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FOREWORD

Since the early days of submarine warfare, the sophistication of the field has escalated dramatically. Defense against this advanced threat prompted on-scene computer aided prediction and detection techniques. The Integrated Command Antisubmarine Warfare Prediction System programs explained in this text assist in providing the necessary edge against the hazard of underwater aggression. The programs integrate oceanographic concepts, specific environmental parameters, and tactical expertise to form a rapid and accurate system for on-scene analysis. This presentation of the operating procedures serves to encourage the use of the Integrated Command Antisubmarine Warfare Prediction System as a vita defensive tool and to disseminate information required for its effective utilization.

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Captain, USN
Commanding Officer

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In combination with NAVOCEANO RP 24A (Volume I), this document promotes intelligent execution and utilization of the ICAPS programs. Discussion of the existing ten ICAPS programs (PROFGEN, FACT, LATRAN, GENRAYT, SHARPS, ACTIVE ASRAP, ADEPS, TAPS, TASDA, and COMPASS) supplies users with insight into the methods, design, and potential of each program. Other sections discuss bathythermograph data collection, on-board analysis, and unique applications of ICAPS resources. Numerous figures present typical ICAPS output.

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1.0 INTRODUCTION

1.1 GENERAL

This manual is designed to supply the user of the Integrated Command Antisubmarine Warfare Prediction System (ICAPS) with the background required to make effective use of the system. It supplements Volume I of the Operating Procedures Manual. That document is aimed primarily at the system operator, giving step-by-step instructions for running the ICAPS programs. The target of this document is the decision maker who determines which products to generate, how they will be used, and on what information they will be based. Criteria for selecting the best available input values are recommended. Techniques for using ICAPS products are examined. Each program in the ICAPS mission software suite is addressed from the point of view of the user, emphasizing capabilities, limitations, and critical factors.

Seawater is the medium of Antisubmarine Warfare (ASW). Seawater is a good transmitter of acoustic energy, but a poor transmitter of electromagnetic energy. As a result sound is the primary means used to detect submarines hiding in the depths. If oceans were the same everywhere a tactic that works in one place would work equally well anywhere else. The ocean characteristics that determine how well sound is transmitted - temperature, pressure, salinity, bottom reflectivity, surface roughness - vary greatly however. Not only do they change from place to place, they vary in time - with seasons, and on shorter time scales. The problem is to define just how sound behaves in the water where and when ASW operations are conducted and to know just how that behavior affects the performance of acoustic sensors. ICAPS helps the ASW specialist rapidly convert readily available ocean temperature data into sonar and sonobuoy performance measures.

ICAPS is a set of computer software for on-scene processing of oceanographic data. It generates environmental, acoustic and tactical decision aid products in direct support of and tailored to local ASW operations. ICAPS is installed in AN/SYK-1 Data Processing Systems at carrier ASW modules (CV-ASWM) and land-based ASW Operations Centers (ASWOC). ICAPS is not designed to substitute for shore-based predictions under normal operational circumstances. ICAPS does provide a rapid response alternative to remotely processed products when communications are restricted by Minimize conditions or jamming. It also features an interactive mode of operation and a set of tactical decision aids not available from shore.

ICAPS software consists of an integrated series of computer programs and extensive files of climatological oceanographic data, threat characteristics, and sonar parameters. An ASW detachment equipped with ICAPS has a self-contained capability to accurately predict detection limits for a variety of acoustic sensors. Different modes, settings, and distributions can be evaluated for specific oceanic conditions. The technical basis of ICAPS is essentially the same as that underlying other modern acoustic prediction methods. Each of these methods uses:

(1) The best available estimate of oceanic conditions in the area of interest, derived from both *in situ* measurements and climatological data,

(2) Mathematical models of acoustic energy propagation, including consideration of refraction, boundary effects, absorption, volume reverberation, and other factors,

(3) Operating parameters for the sensors under consideration, and

(4) Specified target or threat characteristics, or tactical situations.

When the ASW specialist defines the problem and supplies the necessary data, a computer performs the calculations, returning information that contributes to the effective use of available resources.

Volume I of this manual addresses specific program functions and system operating procedures. This volume describes how and where to derive the input data for each program and the major functions each performs. Also included is information concerning processing bathythermograph input data and applications of the output products.

1.2 BACKGROUND

The Naval Oceanographic Office began to study on-scene prediction in 1968 by placing an Automated Shipboard Forecasting System (ASFS) aboard USS WASP. Subsequent installations were made aboard USS INTREPID and USS SARATOGA.

These tests demonstrated that on-board predictions eliminated many communications problems and contributed to effective ASW operations, particularly in the area of sensor selection.

The successful experience with ASFS led to the formation in May 1972 of a more sophisticated project, the Integrated Carrier ASW Prediction System, more recently titled the Integrated Command ASW Prediction System (ICAPS).

The ICAPS Project is divided into two basic phases, development and implementation. The development phase involves selection or design of environmental, acoustic, and sensor performance programs which are modified, tested, and evaluated using the NAVOCEANO UNIVAC 1108 computer. The programs are converted to run on the NOVA 800/820 computers and tested in-house and on-scene. After successful completion of the development phase, programs are implemented into fleet AN/SYK-1 Data Processing Systems.

In order to provide on-scene prediction capability for aircraft carriers under the Acoustic Performance Prediction (APP) program, the NOVA 820 computer Post Processor-2 (PP#2), in the Fast Time Analysis System (FTAS), located in the CV-ASWM is used by the AN/SYK-1 for ICAPS processing. The feasibility and impact of this scheme were first evaluated on the USS AMERICA in May 1977. As a result of this test, ICAPS was approved for nine additional carriers and the Fleet Combat Training Center, Dam Neck, VA. Two other carriers, the USS SARATOGA and the USS MIDWAY were given stand-alone systems. Similar FTAS augmentations are installed at the shore-based VP-ASWOC sites. All initial installations, 12 shipboard and 18 ashore, were completed by June 1981.

The primary function of ICAPS is to predict the impact of ocean conditions on acoustic sensor performance. For this reason it is beneficial for users to have a basic knowledge of oceanography and a working knowledge of ASW support products (ASRAPC, ACTIVE ASRAP, and SHARPS). The ASW Oceanographic and Acoustic Support Products Manual (DIRNAVOCEANMETINST C3160.4) is a concise

reference on basic oceanography with descriptions and directions for use of ASW support products. It is highly recommended that ICAPS users become familiar with the contents of this manual.

1.3 ICAPS PROGRAMS

The ICAPS mission software programs form an integrated series designed to reflect the impact of a changing ocean environment on sensor performance and ASW tactics. Figure 1-1 shows how the ICAPS programs are linked to form a progressive system, leading the user from data on the ocean environment through acoustic information (how sound moves through the seawater medium), to prediction of how his sensors will perform and evaluation of various tactics he may choose to employ. Accordingly the software package is separated into four main sections:

(1) ENVIRONMENTAL - The Profile Generator (PROFGEN) model accepts near surface ocean temperature data, matches it to data from internal files, and computes a complete sound speed profile for use by the acoustic and active sensor performance models. The General Ray Trace (GENRAYT) model spans the boundary between environmental and acoustic categories. It can accept a complete, surface to bottom, sound speed profile, or a complete temperature-salinity-depth series and compute a sound speed profile. GENRAYT processes that data and passes it on to acoustic and sensor performance models. It also produces ray path diagrams showing how sound is bent and reflected as it moves through the water.

(2) ACOUSTIC - The Fast Asymptotic Coherent Transmission (FACT) model computes how much energy is lost as sounds travel between a source at one depth and a receiver at another, depending on the distance between them and the frequency. FACT displays this information in tables and graphics (Propagation Loss curves), and produces ray path diagrams.

(3) SENSOR PERFORMANCE PREDICTION - The active sensor performance models, Ship, Helicopter Active Range Prediction System (SHARPS) and ACTIVE Acoustic Sensor Range Prediction (ACTIVE ASRAP), calculate detection ranges for active sonars and sonobuoys. SHARPS also computes counter-detection ranges for the sonars. The Lateral Range (LATRAN) model solves the passive sonar equation using the propagation loss information from FACT to show how probability of detection varies with range. The Towed Array Prediction System (TAPS) computes and displays area of detection coverage for towed arrays and sonobuoy fields in the vicinity of a task force. It also shows the detection coverage a threat submarine has against the task force itself.

(4) TACTICAL DECISION AIDS - The Automated Detection Prediction System (ADEPS) produces a lateral range curve of probability of detection and computes performance measures for any of 12 sonobuoy patterns. TASDA, the Tactical ASW Sonar Decision Aid, predicts and compares the ability of sonobuoy fields to detect a defined submarine threat. COMPASS, the Computer Assisted Search Series, provides estimates of the target's location and motion behavior to aid in search planning and to recommend new search efforts.

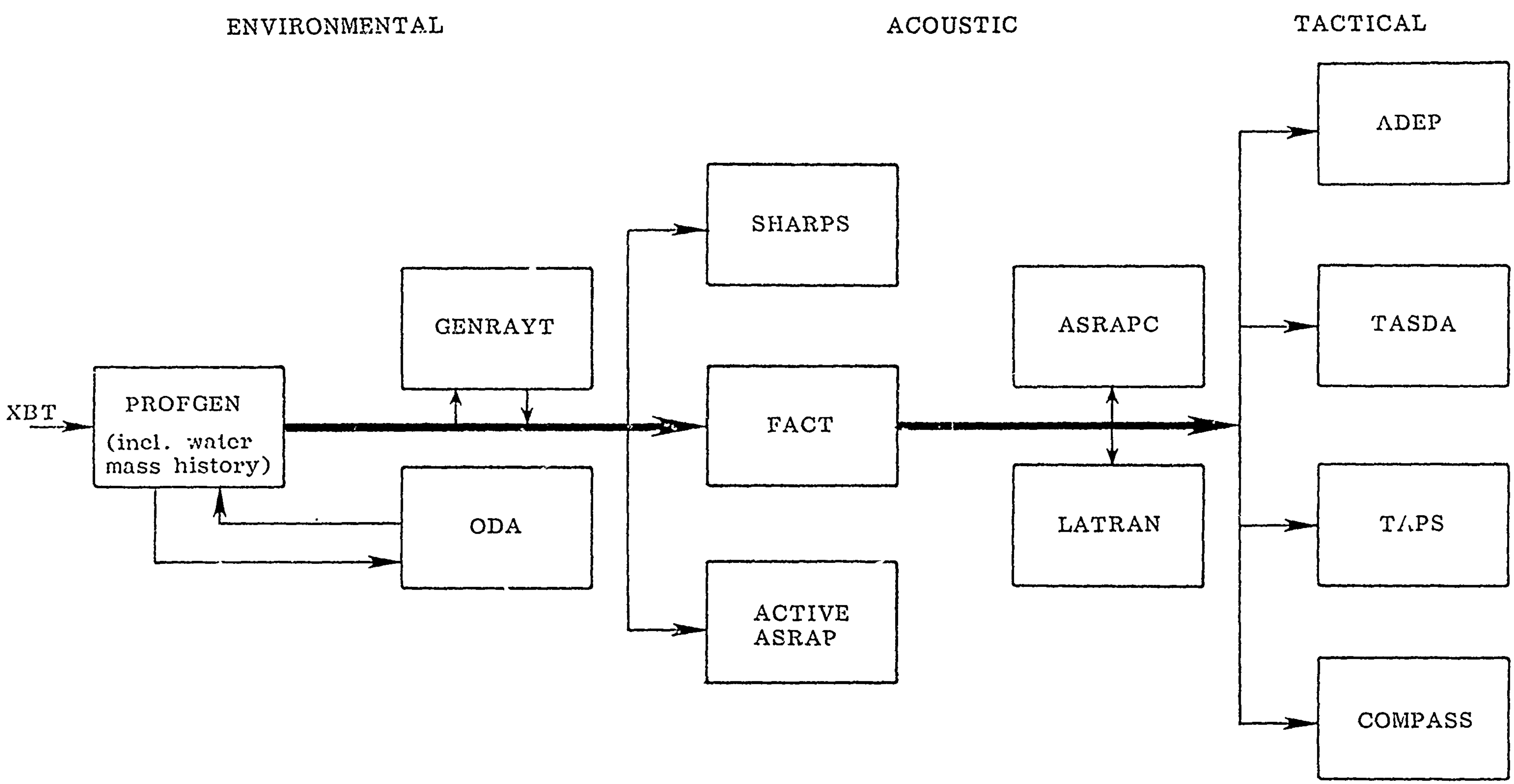


Figure 1-1. Conceptual Diagram of ICAPS Program Flow.

The sections that follow discuss the programs belonging to each of these categories in detail. Input requirements are noted and sources recommended. The information provided to the user is described, in many cases referring directly to reproductions of the actual product displays from the ICAPS screen. A special section is provided to examine several imaginative uses of the ICAPS products.

2.0 OCEANOGRAPHIC ANALYSIS

2.1 OCEANOGRAPHIC DATA EVALUATION AND ANALYSIS

Adequate XBT data coverage in operating areas is needed to delineate water masses, ocean fronts, eddies, and other thermal features that affect sound propagation. However, the limited availability of computer processing time will, in most cases, preclude converting all XBT data collected into sonar range predictions. Therefore, it is important to carefully analyze the ocean environment to determine areas of common thermal structure, ocean fronts, and eddies. Once analyzed, XBT data representative of each water type present can be processed, and products from these data keyed to a water mass boundary chart can be presented to the user. This section is intended to provide guidance in plotting and interpretation of environmental data to determine which profiles should be submitted for acoustic processing.

An oceanographic analyst must coordinate the preparation of on-scene XBT data for the computer operator and establish the requirements for specific ICAPS program runs. XBT drops, reported from naval, research, and commercial vessels on a regular basis, provide the best source of oceanographic data. When several escorts are in company, observations usually are taken by assigned BT guardship duty. In addition, AXBT observations may be available from carrier and land-based air groups. Arrangements should be made to assure that information copies of all XBT data messages (BATHY's) are channeled to the oceanographic analyst. Because of the many errors made in encoding BATHY messages, the analyst should use the original XBT tract to prepare the analysis whenever possible.

Detailed analysis of XBT's to delineate water mass and other thermal features is a complex procedure and entails the predetermination of water mass characteristics and careful matching of observed XBT's to those criteria in order to classify them. The ICAPS PROFGEN program includes routines to automatically classify XBT data by water mass as an aid to on-board analysis. Oceanographic features normally plotted include sea surface temperature (SST), sonic layer depth (SLD), and water mass boundaries. The analyst may wish to plot temperature at the 200-m level (T200) and the temperature difference between 200 and 300 m (DT) as an aid in water mass identification. Plots of temperatures at selected depths, and temperature gradients (in-layer, below-layer) may also prove useful. Some analysts like to determine the temperature gradients immediately above and below sonic layer depth to provide a crude measure of refraction of sonic energy.

2.2 WATER MASSES

The near-surface layer of the ocean is not homogeneous, but is divided into numerous water masses, each having a unique temperature-salinity relationship. Thus, water north of the Gulf Stream is readily differentiated from water to the south of the Stream by its relatively low temperature and salinity. At depths of 200 to 300 m--where seasonal change is minimal, but within the depth range of the XBT--water masses can generally be identified from thermal characteristics alone. For example, during June 95 percent of sea surface temperatures (SST) in slope water fall in a range of 16.3° to 26.6°C, differing little from the range of 21.4° to 27.6°C found in the Sargasso Sea. However, at a depth of 200 m the temperature

ranges differ considerably: 9.4° to 14.5°C in slope water in contrast to 16.5° to 20.0°C in Sargasso water.

Where temperature values at 200 m are similar to adjacent water masses, a second criterion is required to separate them. For example, both Gulf Stream water and Sargasso water have a temperature range of 15° to 25°C at 200 m; however, a layer of near-isothermal water extends to depths exceeding 300 m in the Sargasso Sea, but not in the Gulf Stream. Examination of oceanographic data from the northwestern Sargasso Sea showed that 95% of all observations in that area had a temperature difference between -1.6°C and 0.0°C in the layer between 200 and 300 m. Thus, the temperature difference between 200 and 300 m is used to distinguish Sargasso water from Gulf Stream water. Additional investigation indicated that the temperature difference criterion worked equally well in other areas, and it has been adopted as a "tie breaker" when temperature criteria are similar at the 200-m level. It should be noted that some water masses occur in the near-surface layer only and do not extend to 200 m. Because these changes occur within the depth range of XBT, a single historical file is sufficient for both water masses.

2.3 OCEANIC FRONTS

Considerable changes occur in the temperature-salinity structure in both the horizontal and vertical planes in the boundary zones between water masses. These zones--called oceanic fronts--are areas of intense mixing, generally 10 to 15 nmi in width. Surface temperature differences across a strong front, such as the Gulf Stream, may be greater than 10°C with horizontal gradients approaching 2°C/nmi. It is not unusual for multiple gradients to occur in step-like progressions across a front. Salinity difference across a strong front may approach 2 parts per thousand. The different temperature and salinity regimes found on either side of the front cause density gradients across the front so that the lighter water mass forms a wedge above the heavier (denser) water mass. Thus, the front at depth may be offset considerably from the surface expression of the front. Below is a list of criteria for rating the relative strength of ocean fronts:

	Maximum change in sound speed (m/sec)	Change in Sonic Layer Depth (m)	Depth (m)	Occurrence
Strong	30	150	1000	year-round
Moderate	15-30	30-150	100-1000	year-round
Weak	15	30	100	selected seasons only

Anomalous features such as upwelling and eddies may occur within a water mass. For example, strong winds accompanying a weather system can cause surface water to be blown out of a region, to be replaced by colder, subsurface water. This process is called upwelling. Wind systems may also cause surface water to converge, or pile up, in a region. Convergence of surface water may cause poorly defined fronts such as those found in the Sargasso Sea. Instability of dynamic features cause wave-like meanders to form and progress as waves along a front. Warm eddies of Gulf Stream origin may be injected into slope water northwest of the Stream when meanders become unstable and break off from the main current. Likewise, extreme meanders of the Gulf Stream similar to the ox bow pattern of old rivers may entrap slope water, thus causing cold eddies in the Sargasso Sea. Eddies range from 50 to 200 nmi in diameter and can be expected to retain

the circulation pattern of their origin. Eddy life span varies from weeks in the case of a warm eddy to as long as two years for a cold eddy. Although eddies and meanders have most frequently been described along frontal systems such as the Gulf Stream and the Kuroshio, weaker anomalies no doubt occur near weaker fronts.

Longevity and intensity of fronts and eddies are greatly affected both by existing conditions of contiguous water masses and the overlying atmosphere. Cold eddies, being denser than the surrounding warm water, will sink at a rate of up to 1 m per day. Thus, an old, cold eddy may not be evident from surface observations alone. Surface warming of fronts during summer frequently masks the surface indications of a front; however, subsurface horizontal temperature gradients and sound channels may exist throughout the summer. Warm eddies lose heat to the atmosphere faster than the surrounding cold water in winter with the result that surface cooling may mask the eddy. Masking also occurs in summer when the surface of the surrounding cold water may be warmed to near that of the eddy.

2.4 FRONTAL ACOUSTICS

An oceanographic front is not only a boundary separating temperature-salinity regimes, but also separates acoustic regimes. Because dynamic instability is inherent to frontal regions, acoustic conditions can be expected to vary considerably. Variations that occur during a frontal transit include:

-- Surface sound speed may differ as much as 30 m/s on either side of the front.

-- Differences in sonic layer depth of 300 m can exist on either side of the front depending upon season.

-- Changes in in-layer and below-layer gradients usually accompany changes in surface sound speed and sonic layer depth.

-- The depth of the deep sound channel axis may differ by as much as 800 m on either side of the front.

-- Increased biological activity generally found along a front will increase ambient noise and scattering.

-- Sea-air interaction in a frontal zone can cause a dramatic change in sea state when wind opposes ocean currents, thus increasing ambient noise.

-- Refraction of sound rays passing through a front at oblique angles may cause bearing errors.

-- Interaction of the water masses on either side of the front may cause near-surface sound channels (temperature inversions).

2.5 ACOUSTIC DATA MANIPULATION

Acoustic data normally plotted include SLD, areas where convergence zone (CZ) mode of sonar ranging is possible, and extent and axial depth of near-surface sound channels. Because sound speed data are rarely available to Fleet ASW units, sonic structure is normally estimated from thermal structure data. Therefore, the previous comments on processing of oceanographic data apply equally well to this section.

Sound speed is affected by depth and salinity as well as temperature. Although salinity has relatively little effect, depth (pressure) may have considerable effect on the determination of SLD. Where a slightly negative temperature gradient exists, the effect of depth may be sufficient to cause the sound maximum to occur at the bottom of the layer. For example, suppose that a near-isothermal layer occurred with a surface temperature of 15.1° and a temperature of 14.9° at a depth of 50 m. The 0.2°C temperature decrease in the layer implies a decrease in sound speed of 0.6 m/s. However, the effect of the 50-m depth increase causes an increase in sound speed of 0.8 m/s for a net increase of 0.2 m/s. SLD will thus be at the bottom of the slightly negative temperature layer.

A similar effect occurs in areas such as the Sargasso and Mediterranean Seas and in the Arctic, where a seasonal thermocline develops above a near-isothermal layer during spring and summer. A sound minimum occurs at the bottom of the seasonal thermocline and the effect of depth overrides the slightly negative temperature gradient forming a so-called "depressed" sound channel. The channel axis will normally be at the top of the layer.

When sound speed near the ocean floor is greater than that near the surface, some of the sonic energy originally refracted downward toward the bottom will be refracted upward toward the surface, forming a convergence zone. Range, width and intensity of the CZ is a function of depth excess; that is, the vertical distance between critical depth and the bottom. Depth excess generally must be at least 1000 m if CZ propagation is to be operationally useful. Range to the inner edge of the first CZ annulus varies between 33 and 70 kyds, depending upon geographic area. Areas of high insonification at ranges less than 33 kyds, or where depth excess is insufficient for CZ propagation, are probably the result of bottom bounce (BB) propagation.

2.6 PLOTTING AND ANALYSIS

The experienced analyst develops techniques over the years that permit rapid plotting and analysis of environmental data. The following suggestions are provided as an aid in developing these techniques. In the example given only a portion of available data is used. The decision as to what data should be plotted depends upon what information is required for subsequent briefings. For example, determination and plotting of the temperature difference between 200 and 300 m (DT) is meaningless if it is not required for water mass identification.

The initial step in preparing an analysis is the collection and examination of available data. Obviously erroneous data should be discarded and questionable data identified. The analyst is encouraged to enter the data in a log both as an aid in preparation of the analysis and as a record for later reference. SST is generally available from XBT observations and injection intake thermometer reports. The latter data are particularly subject to errors and must be used with care. Temperature values at specified depths (200 and 300 m in the sample given) and, where desired, additional information are computed.

When ICAPS is being used as an analytical tool for tactical decision making, the analyst may wish to plot temperature at the 200-m level (T200) and the temperature difference between 200 and 300 m (DT) as an aid in water mass identification. The temperature difference between 200 and 300 m is computed using the relationship:

$$DT = T300 - T200$$

where T300 is the temperature at 300 m.

Some analysts like to determine the temperature gradients immediately above and below sonic layer depth to provide a crude measure of refraction of sonic energy. The in-layer gradient (ILG) giving temperature gradient per hundred meters between the temperature at the surface (SST) and the temperature at the SLD (TSLD) is given by the realtionship,

$$ILG = (TSLD - SST) \times 30/SLD.$$

The below-layer gradient (BLG) is defined as

$$BLG = (TL - TSLD) \times 30/L,$$

where L is the thickness of the layer considered below SLD (normal 25 or 30 m) and TL is the temperature at the bottom of that layer.

In each of the above equations the values are adjusted to reflect the gradient per 30 m, thus permitting comparison among observations. Values that differ considerably from neighboring values should be treated with suspicion. Variability in thermal structure data can be expected near oceanic fronts. Although XBT traces normally have an isothermal or slightly negative ILG, positive gradients are not unusual in frontal, coastal, and polar regions. An increase of temperature greater than 0.1°C at depths below 200 m should be questioned.

Choice of plotting base and method of plotting are the prerogative of the analyst. Where a mercator base is desired, nautical charts or plotting sheets are recommended, but graph paper or maneuvering boards also may be used.

Use of a summary sheet is helpful in preparing the data for plotting. A sample summary sheet is shown as figure 2-1 with fictitious BATHY and SST data. Data entered on this sheet will be used later to prepare a sample analysis. Ship data time group name (DTG), position, thermal structure data at various levels, SLD, and water mass are generally sufficient. Water mass (W.M.) is determined using T200 and DT. Any observations not meeting the quality control criteria discussed earlier or falling outside water mass criteria given in PROFGEN should be used with caution. ICAPS can store XBT profiles during the data processing routine and the analyst can rapidly recall this information. If an XBT probe malfunctioned below the surface layer, SST and SLD may be used if in agreement with surrounding observations.

After this summary sheet has been completed and a preliminary error check made, the data should be transferred to the plotting sheet. Figure 2-2 shows a plotting sheet with position, DTG, and applicable data entered from the summary sheet. Symbols or colored pencils may be used to identify each ship--again this is the analyst's choice. Position errors are frequently revealed by computing the speed of advance (SOA) between successive observations. For example, an SOA of over 56 kts. is required to achieve the 07/0000 position of the MCCANDLESS as recorded on the sample plot. Therefore, this observation should be discarded if the correct position cannot be determined from other sources (Dead Reckoning Tracer plot, Quarter master's log, etc.). Pertinent information--such as SST, SLD, and water mass--may be plotted either on the base chart or on overlays of tracing paper (figures 2-3 and 2-4). It is helpful to analyze SST first because these data are more plentiful, thus permitting definition of the more obvious ocean features. Subsequent analyses--such as the SLD analysis shown--normally are configured to agree with the SST analysis.

During the plotting and analysis phases the analyst must apply his knowledge of oceanography with respect to (1) elimination of data that vary markedly from

SHIP	DTG	LAT	LON	SST	SLD	T200	T300	DT	W.M.
		N	W	°C	M	°C	°C		
AMERICA	6/2200	37-24	71-13	26.2	35	18.5	11.1	-7.4	GS
	2300	37-27	71-35	25.8	18	18.4	10.8	-7.6	GS
	7/0000	37-31	72-04	15.2	6	12.8	11.4	-1.4	SL
	0100	37-35	72-30	16.3	12	11.9	8.0	-3.9	SL
	0200	37-42	72-56	15.8	11	10.8	10.0	-0.8	SL
BROWN	6/1300	36-50	73-47	16.5	15	12.4	8.3	-4.1	SL
	1400	36-35	73-26	17.0	8	12.9	9.6	-3.3	SL
	1500	36-24	73-03	24.3	30	18.7	12.0	-6.7	GS
	1600	36-13	72-45	25.2	18	18.5	14.8	-3.7	GS
	1700	36-03	72-22	23.0	10	18.3	18.1	-0.2	SA
	1800	36-08	71-55	23.2	15	18.8	18.0	-0.8	SA
	1900	36-24	71-34	23.4	15	18.1	16.6	-1.5	SA
	2000	36-41	71-27	23.7	18	18.2	17.8	-0.4	SA
	2100	36-59	71-30	24.1	20	18.1	12.3	-5.8	GS
	2200	37-14	71-38	26.1	31	17.8	14.8	-3.0	GS
	2300	37-24	71-51	19.3	2	14.9	8.0	-6.9	SL
	7/0000	37-35	72-13	16.0	10	11.8	8.4	-3.4	SL
	0100	37-42	72-38	29.5	8	11.3	10.9	-0.4	SL
McCAND	6/1800	37-22	73-17	23.2	32	16.1	13.8	-2.3	GS
	1900	37-04	73-05	22.8	20	16.3	13.7	-2.6	GS
	2000	36-49	72-75	19.7	3	13.8	8.8	-5.0	SL
	2100	36-33	72-39	26.0	28	18.3	13.9	-4.4	GS
	2200	36-16	72-21	24.3	10	18.2	16.9	-1.3	SA
	2300	35-57	72-04	23.1	12	18.4	17.6	-0.8	SA
	7/0000	35-29	71-05	22.2	14	18.0	16.7	-1.3	SA
	0100	35-29	72-03	22.1	12	18.1	16.9	-1.2	SA
	0200	35-29	72-22	22.8	15	18.0	17.3	-0.7	SA
	0300	35-28	72-39	23.0	12	18.3	17.8	-0.5	SA
	0400	35-28	73-00	23.1	10	18.2	17.5	-0.7	SA
	0500	35-29	73-28	25.8	30	18.1	11.6	-6.5	GS
	0600	35-50	73-40	23.1	3	14.7	13.3	-1.4	SL
	0700	36-12	73-56	17.3	10	12.4	11.5	-0.9	SL
SHIP	6/2200	35-54	72-55	24.8					
	6/2300	37-30	72-48	16.8					
	6/1900	37-05	72-42	18.6					
	7/1200	36-50	72-30	24.3					
	7/1700	37-00	71-56	25.5					

Figure 2-1. Sample Oceanographic Data Summary Sheet.

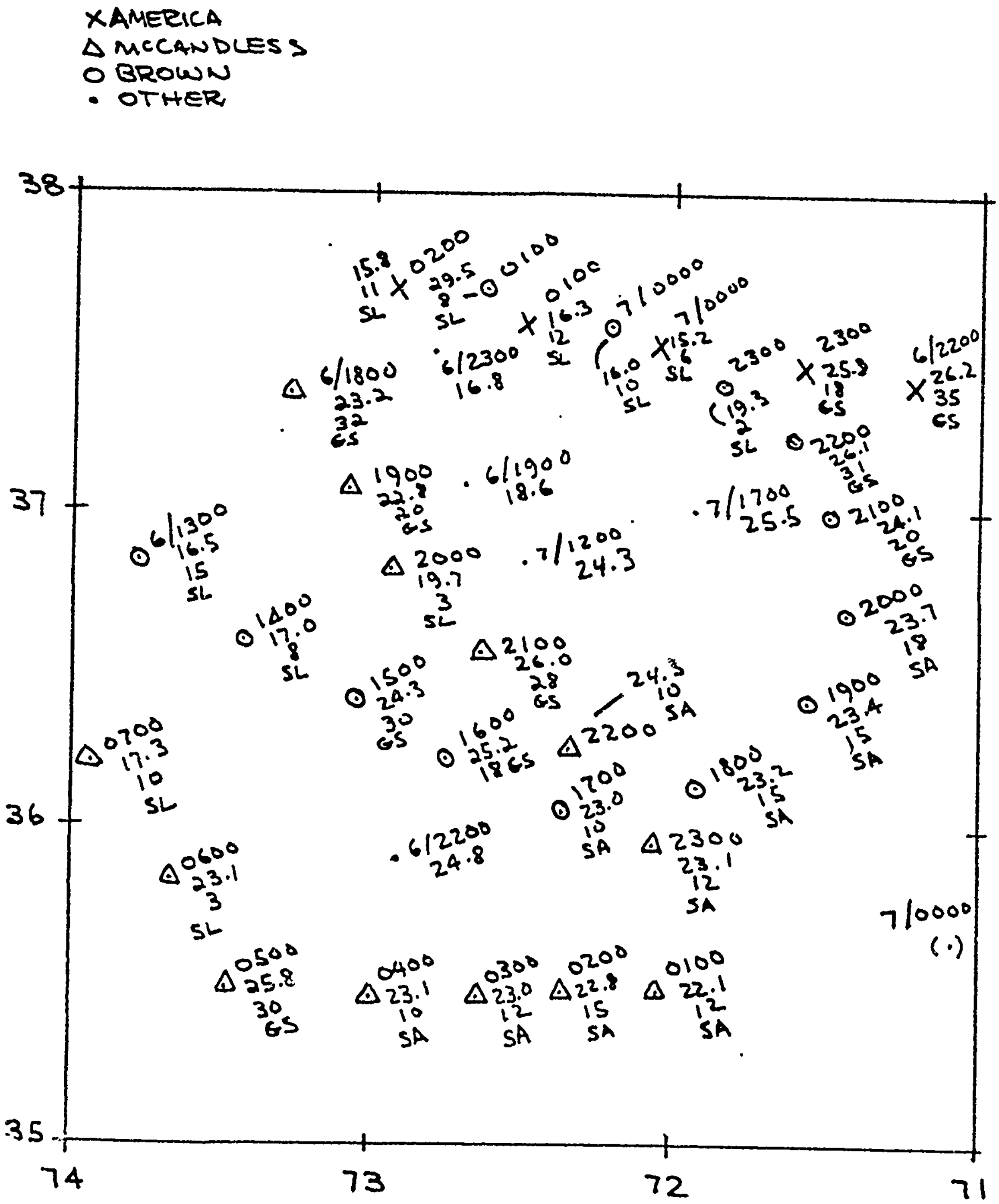


Figure 2-2. Rough Oceanographic Plotting Sheet.

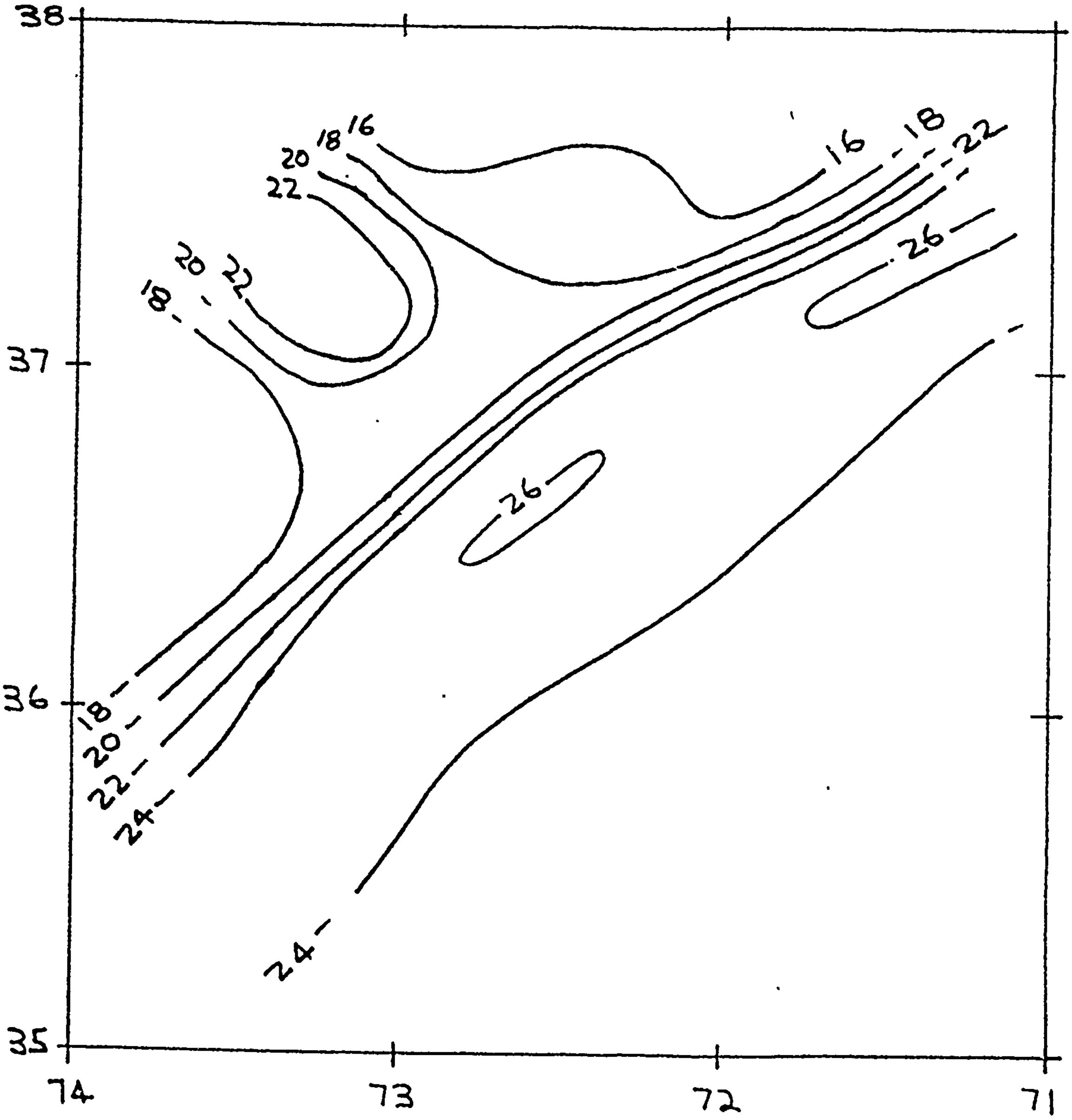


Figure 2-3. Smooth SST Analysis.

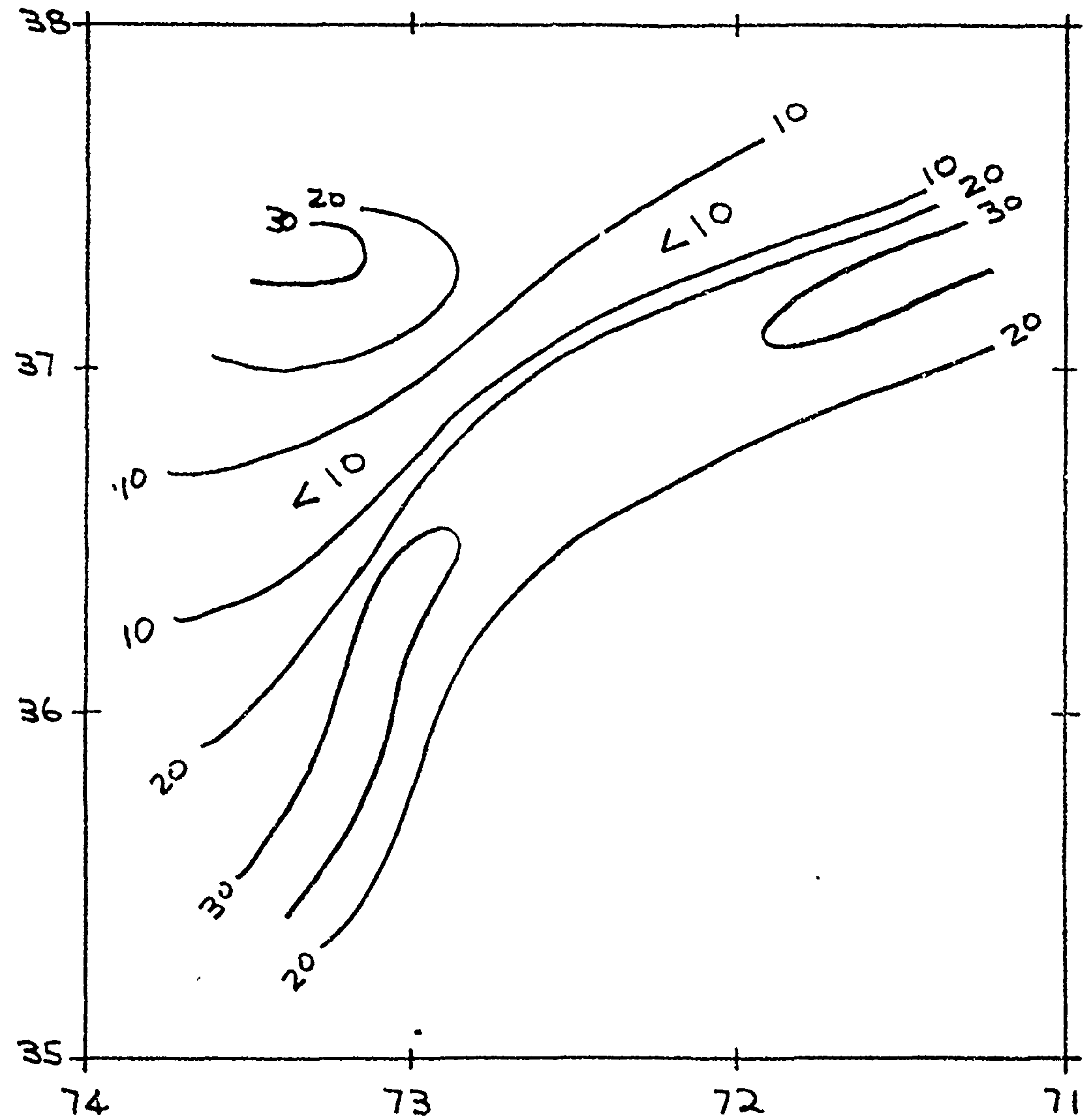


Figure 2-4. Smooth SLD Analysis.

other data and (2) the properties of mesoscale oceanic features of the area. For example, the 7/0100 XBT drop made by the BROWN showed an SST of 29.5°C; some 6°C higher than other data in the same general area. Although SLD, T200, and T300 were reasonable, uncertainty as to the accuracy of the observation prohibits its use in the analysis. However, the 6/1800 and 6/1900 data collected by the MCCANDLESS to the southwest of the aforementioned BROWN observation show characteristics of Gulf Stream water. The presence of cold water adjacent to the MCCANDLESS observations indicates that the warm water is isolated from the Gulf Stream as an eddy.

Knowledge of oceanic processes is helpful in maintaining objectivity. In frontal zones, where water masses of different temperature-salinity characteristics occur, it is common for the warmer, more saline (and thus lighter) water to override the colder, less saline water with the result that SLD may approach the surface. In the example given, a zone of near-zero SLD is likely near the oceanic front separating slope water and Gulf Stream water.

The completed water mass analysis (figure 2-5) can now be drawn. Prior to labeling the analysis, XBT traces representative of each water mass should be selected. In selecting a typical trace the analyst should especially consider shape of the trace, T200 SLD, and SST. Once a trace has been selected, its position should be plotted on the analysis along with identification (A through D in the analysis). Name of water mass and variability of SST and SLD now can be added to the water mass on the analysis.

The desired suite of ICAPS acoustical and tactical products may now be made using the representative XBT traces selected for each frequency and source depth /hydrophone depth desired. Other environmental data (wave height, bottom classification, water depth, ambient noise, scattering coefficients) will be required to compute passive and active sonar ranges.

Items such as predicted sonar range (in-layer, cross-layer, below-layer), best depth, areas where CZ or BB modes sonar operation may be used, etc., should be added to the analysis. The computed data are now available to develop ASW tactics suitable for each water mass. When completed, a briefing package is available providing near real-time environmental and tactical information to operational ASW forces.

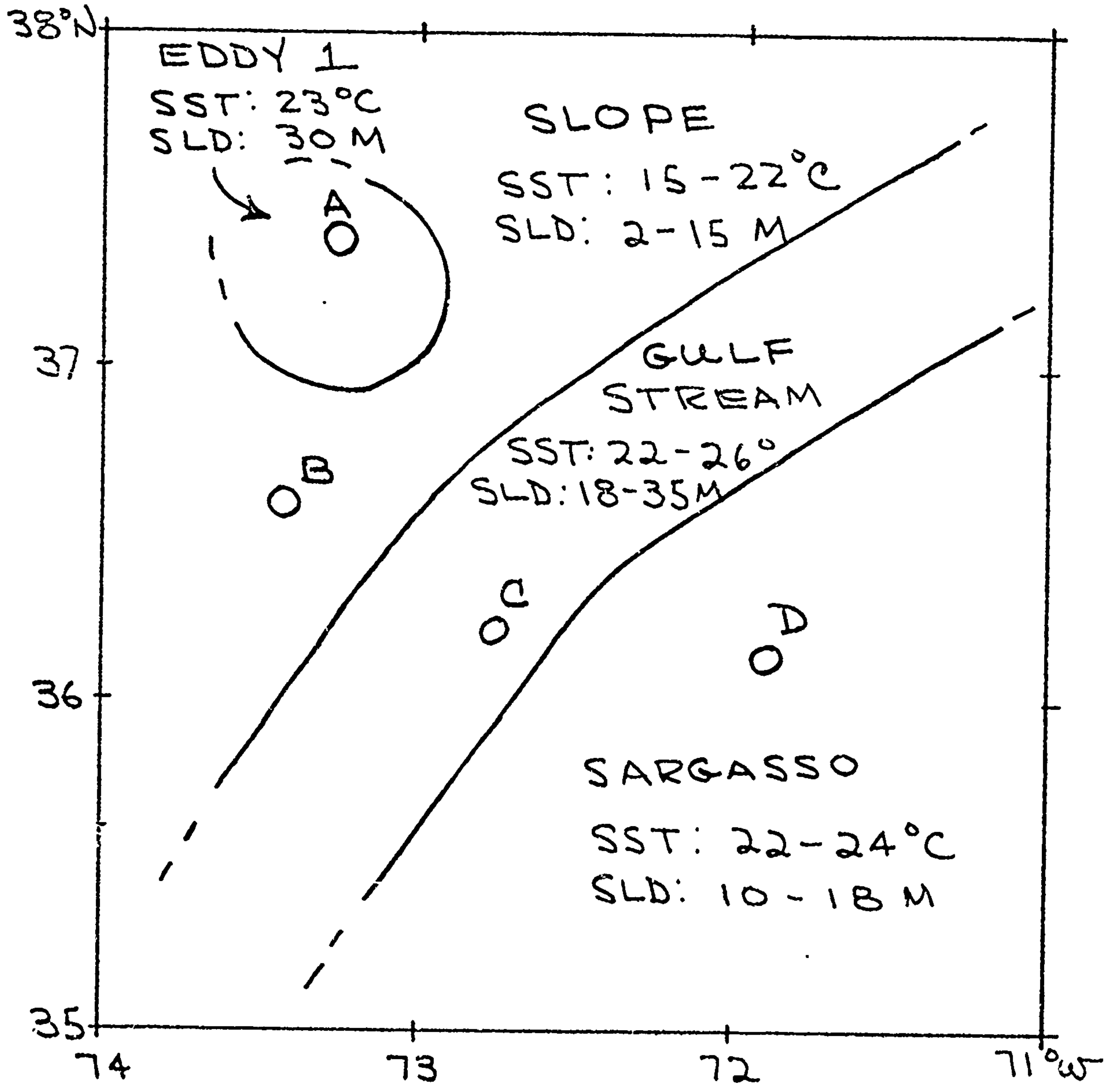


Figure 2-5. Smooth Water Mass Analysis.

3.0 PROFILE GENERATOR (PROFGEN)

3.1 GENERAL

The purpose of ICAPS is to help the ASW specialist know the impact of ocean conditions on his sensors. Thus the Profile Generator (PROFGEN) program, which allows the user to enter relevant ocean data into the program flow, is the key software element in ICAPS. In a broad sense, PROFGEN consists of the program accessed by the user and a set of data files containing ocean data from historical observations. PROFGEN employs a unique approach based on established oceanographic principles to combine available ocean data with historical information.

This section describes the PROFGEN model, beginning with a basic discussion of acoustic oceanography. It examines the structure of the data base and deals with the program's functions; how it incorporates data, how it selects historical data, how it computes sound speed. It guides the user in selecting data sources, controlling the quality of inputs, and interpreting the displays.

3.2 OCEANOGRAPHIC BACKGROUND

The variability of the ocean environment creates the need for acoustic sensor performance predictions. If the ocean were the same everywhere, sonars and sonobuoys would perform the same everywhere. But the ocean has distinct characteristics depending on location, season, local weather, and other factors. It is the nature of the ocean that most of the variability occurs near the surface. The basic vertical temperature structure of the ocean, shown in figure 1-3, consists of three layers: a relatively shallow surface layer that is mixed by wind and convection (sinking of water cooled at the surface), a deep body of water of more uniform, colder temperature, and a layer between them in which temperature decreases rapidly with depth. This transition layer, or thermocline as oceanographers call it, acts to isolate the deep water from the surface layer that responds to changes in wind and weather. The deep water, therefore, is little affected by outbreaks of weather or changes in season. Most of the variability is restricted to the surface layer. Fortunately, the near-surface ocean can be sampled rapidly, without interfering with a warship's or aircraft's tactical functions, using the expendable bathythermograph (XBT). The XBT produces a graph (figure 3-1) of temperature against depth. Of the three parameters - temperature, pressure and salinity - that determine sound speed, temperature and pressure are usually by far the more significant. Pressure is proportional (with insignificant error) to depth. Thus, the XBT supplies the critical data needed to calculate sound speed at any depth in its range. Below the layer sampled by the XBT, changes are regular and smooth, and are not as large as nearer the surface. This too is fortunate, because sampling the deeper water requires special equipment and lengthy procedures that are incompatible with tactical operations. The relatively constant nature of deep ocean water is the basis on which most data bases rely. Simple seasonal or monthly averages are in most cases adequate to describe the characteristics of the water below the thermocline.

Some areas, however, can be occupied by different types of water from time to time. Types of water that can be identified by a unique set of temperature and salinity characteristics are called water masses. The influence of

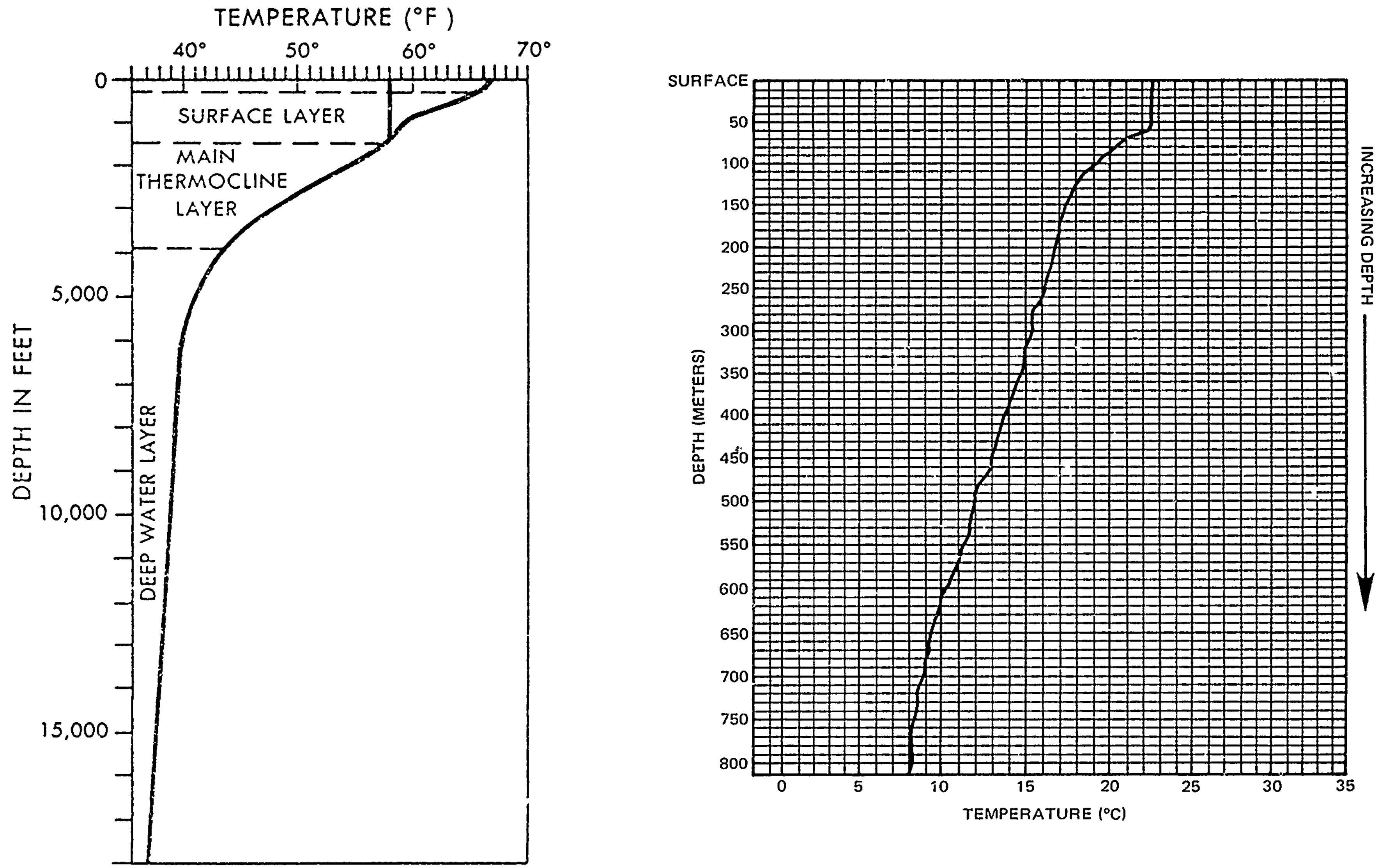


Figure 3-1. Basic Temperature Structure of the Oceans with Expendable Bathythermograph (XBT) Record of Near-Surface Temperature Profile.

these water masses extends to the deep water. Often the differences are small, but near ocean fronts large differences can occur over short distances. The effects of these different characteristics on sound transmission can be extreme.

If a data base is constructed by averaging the characteristics of several distinct water masses (that occupy the same area at different times), the resulting set of characteristics may not be representative of any existing water mass. Many data bases try to deal with this problem by using a finer geographic grid or shorter time periods. This approach presents problems because frequently there are no data points in a given area for a given time period, or too few data points to provide reliable statistical information. The ICAPS data base uses relatively large areas and seasonal time periods in order to have enough samples for reliable analysis. The areas were selected on the basis of relatively uniform oceanographic characteristics. Each area comprises from one to five water masses. This approach makes effective use of the unchanging relationship of temperature, salinity and depth characterizing a water mass. At the same time it accommodates the variability resulting from the movement of water masses into and out of an area.

3.3 PROGRAM FUNCTIONS

PROFGEN is the entry point to ICAPS. Using PROFGEN the operator enters temperature-depth data points from an on-scene XBT or AXBT. The program analyzes that data, selects a matching water mass from the data base, and merges the two. The result is a continuous temperature-depth profile extending from the ocean surface to the bottom. That profile, which represents the best available information on the variable near-surface layer, is used to compute and store a sound speed profile.

Occasionally ICAPS runs will be required for an area and time where there is no recent on-scene BT. During mission planning for example, the operator may know the date and location of the requirement but he may not have a temperature profile to enter. In these cases PROFGEN will now select a typical XBT (TXBT) from files. For each water mass in an ICAPS subarea, a set of 12 monthly TXBT's has been selected and stored as the most representative of all XBT observations for that water mass and area. The program will treat the TXBT the same as a BT entered by the operator. ICAPS products from TXBT's can be useful for planning and for taking a pre-exercise look at an operating area.

The date and location of the XBT and the temperature-depth points that define the thermal profile are entered via the terminal keyboard in response to prompts from the program. PROFGEN accesses the historical files according to the date and location supplied, and retrieves the appropriate water mass for merging by examination of the XBT data. Temperature windows characterizing the water masses at 200 m are compared to the interpolated XBT value at that depth. If the water masses cannot be distinguished on this basis, the temperature gradient between 200 m and 300 m is applied to resolve any ambiguity. Only the portion of the selected historical temperature profile that is deeper than the deepest point on the XBT trace plus 50 m is retained. Those temperature-depth points are merged into the XBT data in a manner that produces a smooth temperature profile from the ocean surface to the bottom. Figure 3-2 illustrates the PROFGEN merge. The historical salinity profile is unaffected by this procedure unless an inversion in the BT trace indicates an unstable density distribution.

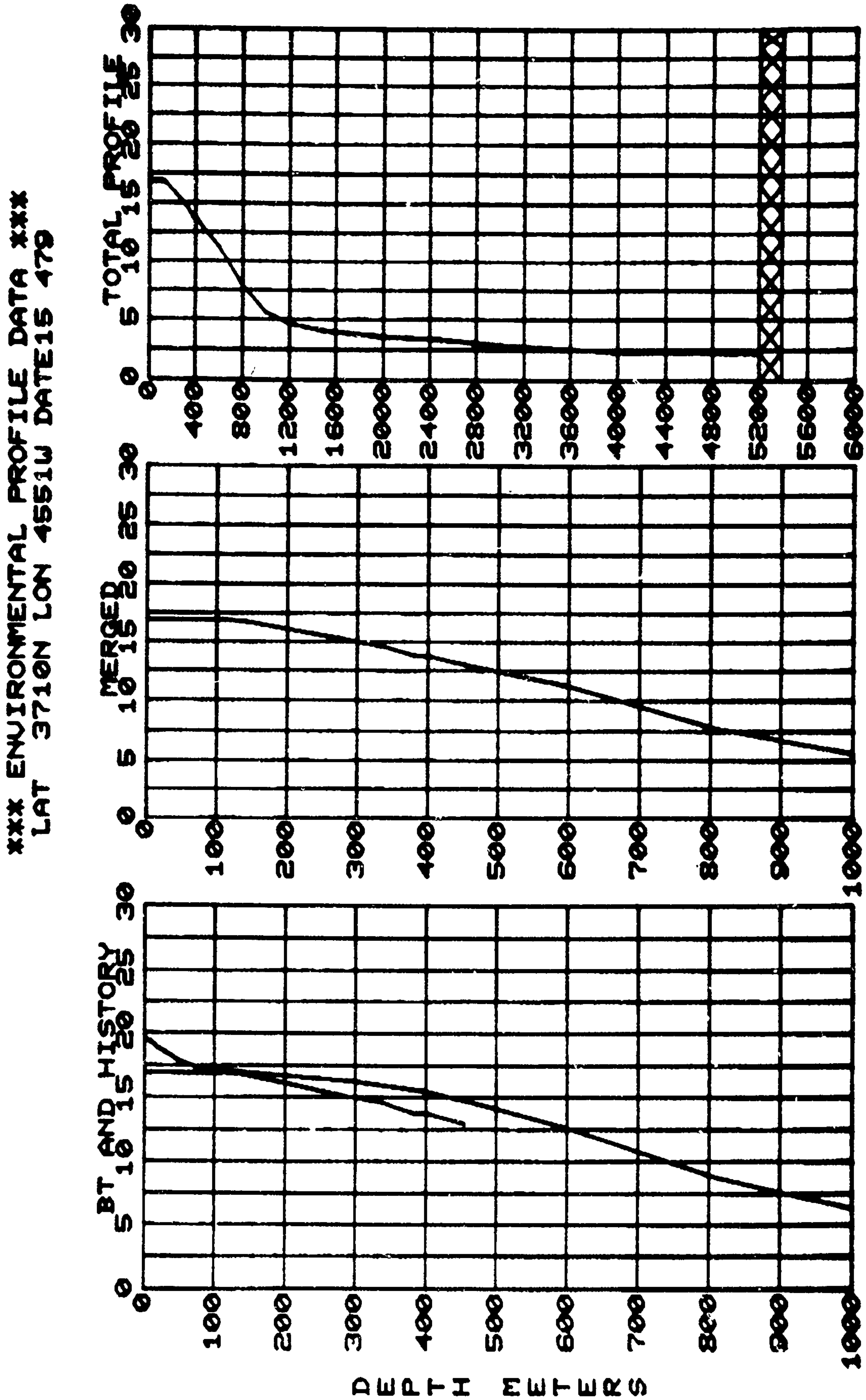


Figure 3-2. PROFGEN Merge Graphic

Where heavier water overlying lighter water is indicated, a correction is applied to the salinity to eliminate the instability. The salinity adjustment, temperature profile merge, and development and structure of the water mass history file are all discussed in detail in NOO RP-19, The ICAPS Water Mass History File.

Bottom depth is accessed from a storage file that contains gridded values of the deepest charted depth contours from Naval Oceanographic Office Special Publication SP 1304 by areas one-half degree on a side. Province numbers for acoustic bottom loss are stored at the same geographic resolution. Low frequency (less than 1000 Hz) bottom loss is calculated using the Interim Bottom Loss Upgrade (IBLUG) provinces (IB1) and curves. NAVOCEANO high frequency bottom loss provinces (IB2) and curves are used above 1000 Hz. To avoid a discontinuity at 1000 Hz a linear interpolation between the two sets of curves is performed over the frequency band 1000-1500 Hz. The curves relate bottom loss (in dB per bounce) to grazing angle and frequency. The curves used by ICAPS are those selected by the Navy's Acoustic Performance Prediction Program for the master data base for on-scene acoustic prediction systems. If he desires, the operator may override the PROFGEN selections for bottom depth or water mass.

Since the set of water masses considered for merging with the observed data is determined by the data and location of the XBT, it is sometimes advisable, particularly when the sample occurs in months adjacent to the change in seasons or in the vicinity of the geographical boundaries of the water mass regions, to attempt merges across those artificial boundaries. This can be done by dummying dates or positions to accommodate an early (or late) change of season or a shifting of water mass boundaries. Care must be exercised, however, to prevent unintended changes of bottom types or other parameters. The operator can correct any input changes that might occur.

PROFGEN uses the temperature-salinity-depth data that result from the temperature merge and salinity adjustment to compute sound speed via Wilson's equation. PROFGEN also computes sonic layer depth (SLD). The input data and sound speed profile (SSP) are stored in the intermediate work file Z999ICAP: IM for use by subsequent acoustic programs.

Figure 3-3 summarizes the data processed by PROFGEN and the resulting sound velocity profile. The display heading identifies the location and date of the XBT observation. It also supplies the sonic layer depth in both meters and feet, as well as low frequency and high frequency bottom loss categories, IB1 and IB2. Three columnar groupings present the BT data input, the temperature, salinity and depth combinations retrieved from the water mass history file, and the resulting merged and computed profiles. Figure 3-4 is a graphic display of the sound velocity profile, surface to bottom and for the upper 300 meters or 1000 feet, depending on the units used to input the BT data.

3.3.1 Applications

By examining the sound speed profile and other PROFGEN output the experienced ASW technician learns a great deal about available acoustic transmission paths and the performance of his sensors. The strength of the surface duct, for instance, is indicated by the magnitude of the positive sound speed gradient in the layer and the layer depth. Low frequency sound is not trapped in the surface duct. Theory suggests an upper limit to wavelength λ, which corresponds to a lower limit to frequency, trapped in an isothermal duct:

*** ENVIRONMENTAL PROFILE DATA ***
LAT 3710N LON 4551W DATE 15 479
SLDM 140. SLDF 459. IB1 IB2

BT DATA

DEP (M)	TEMP (C)
0.	16.90
110.	16.90
140.	16.80
280.	15.20
333.	14.70
380.	13.80
405.	13.70
455.	13.00

RETRIEVED DATA

DEP (M)	TEMP (C)	SAL (PPT)
0.	19.48	36.40
10.	19.18	36.40
20.	18.81	36.39
30.	18.40	36.39
50.	17.76	36.39
75.	17.35	36.38
100.	17.17	36.38
125.	17.05	36.37
150.	16.94	36.36
200.	16.74	36.33
250.	16.51	36.29
300.	16.24	36.25
400.	15.44	36.11
500.	14.22	35.89
600.	12.63	35.65
800.	8.93	35.23
1000.	6.32	35.10
1200.	5.10	35.05
1500.	4.31	35.01
2000.	3.71	34.97
2500.	3.34	34.96
3000.	2.93	34.94
4000.	2.33	34.90
5000.	2.28	34.89

MERGED DATA

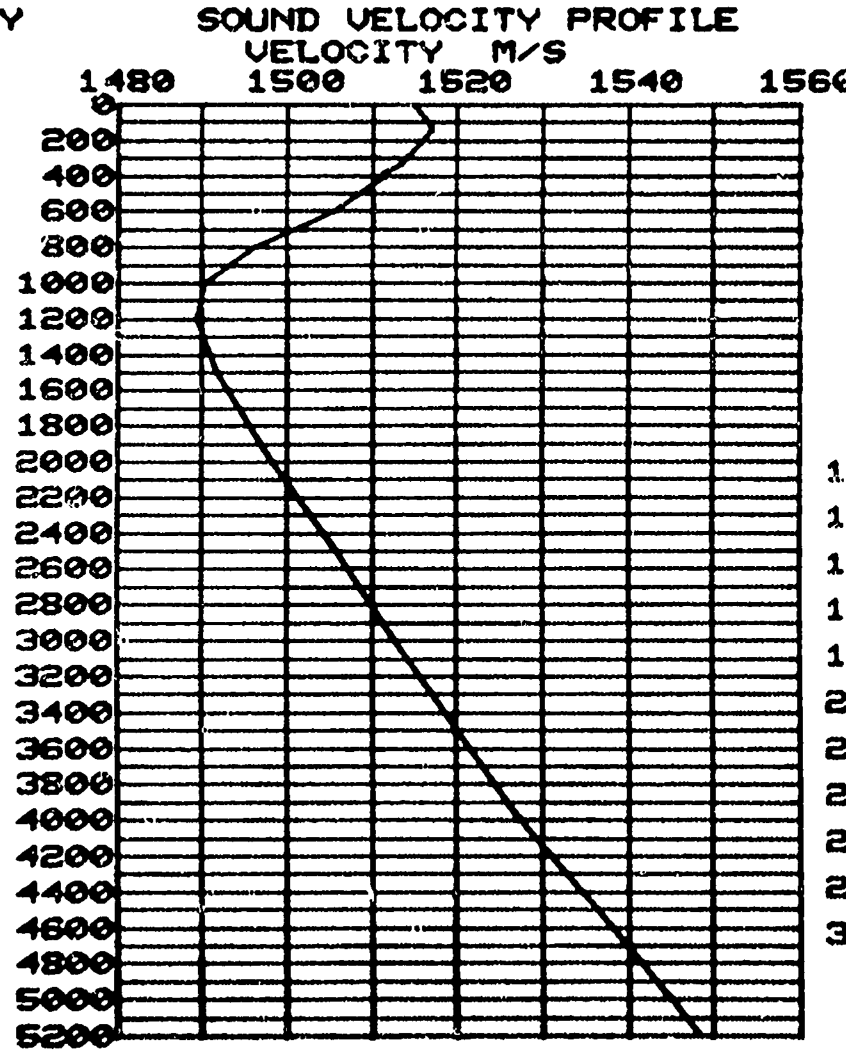
DEP (M)	TEMP (C)	SAL (PPT)	VEL (M/SEC)
0.	16.90	36.40	1514.94
110.	16.90	36.38	1516.71
140.	16.80	36.36	1516.89
280.	15.20	36.27	1514.16
333.	14.70	36.20	1513.38
380.	13.80	36.11	1511.13
405.	13.70	36.10	1511.20
455.	13.00	35.99	1509.56
600.	11.16	35.65	1505.20
800.	7.91	35.23	1496.02
1000.	5.61	35.10	1490.13
1200.	4.61	35.05	1489.30
1500.	4.03	35.01	1491.85
2000.	3.60	34.97	1498.44
2500.	3.29	34.96	1505.67
3000.	2.91	34.94	1512.63
4000.	2.33	34.90	1527.54
5000.	2.28	34.90	1545.10
5200.	2.27	34.90	1548.65

*****PROFILE COMPLETED*****

Figure 3-3. PROFGEN Data Summary

LAT 3710N LON 4551W
DATE 15 479

DEPTH (M.)	VELOCITY
0.0	1514.9
110.0	1516.7
140.0	1516.9
280.0	1514.2
333.0	1513.4
380.0	1511.1
405.0	1511.2
455.0	1509.6
600.0	1505.2
800.0	1496.0
1000.0	1490.1
1200.0	1489.3
1500.0	1491.9
2000.0	1498.4
2500.0	1505.7
3000.0	1512.6
4000.0	1527.5
5000.0	1545.1
5200.0	1548.7



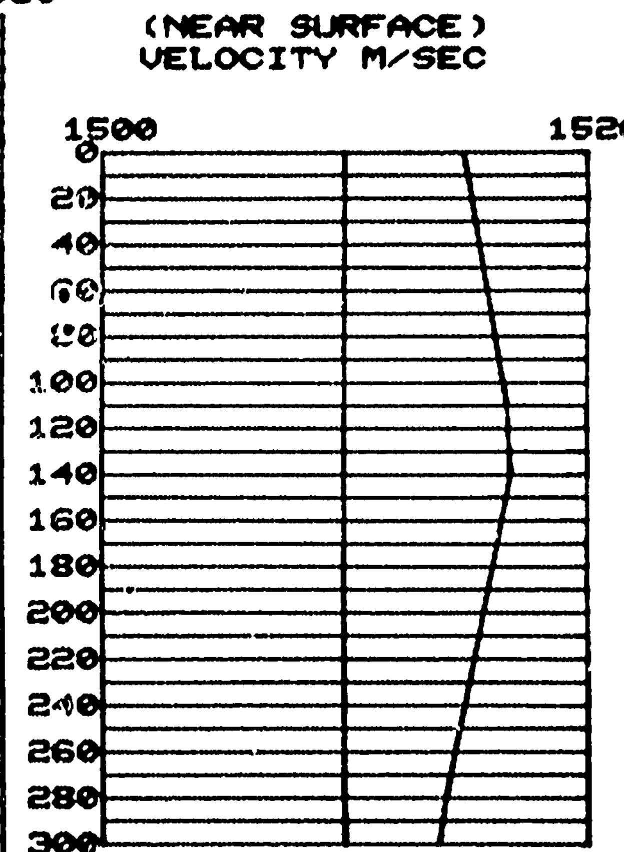


Figure 3-4. PROFGEN Sound Speed Profile

$$\lambda max \cong 4.7 \times 10^{-3} H^{3/2}$$

where λmax = maximum wavelength (feet), and

H = layer depth (feet).

For a duct 100 feet thick, λmax is 4.7 feet, which corresponds to a low frequency cutoff equal to 1100 Hz. A layer 370 feet thick is required to trap 150 Hz sound. The cutoff effect is gradual; energy at wavelengths much greater than λmax is significantly reduced. Wavelengths much shorter are more rapidly attenuated by absorption and leakage. Thus the optimum frequency for long range detection in the layer, the cutoff frequency, may be quickly calculated from the PROFGEN sonic layer depth.

The quality of any sound channel is a function of its width (the depth difference between points of equal maximum velocity above and below the channel axis) and its magnitude (the velocity difference between the axis velocity and the velocity at the channel limits). The presence, quality, and accessibility of a sound channel to available sensors are identifiable from the sound speed profile (figure 3-4).

Convergence zones may exist where the sound speed at the bottom exceeds the sound speed at the source depth. Experience permits the analyst to estimate convergence zone range and width from the shape of the sound speed profile.

The bottom loss types displayed in PROFGEN are measures of the degree of reflection or absorption of sound striking the bottom. They give an indication of the availability of the bottom bounce mode of propagation.

Thus, applying basic knowledge of underwater acoustics to the information supplied by the PROFGEN program helps the operator decide sensor depth settings, optimum frequency bands for search, and buoy patterns or other tactics. DIRNAVOCEANMETINST C3160.4, ASW Oceanographic and Acoustic Support Products Manual Volume 1, contains guidance for tactical interpretation of sound speed profiles. All Naval Oceanography Command Facilities and Detachments hold copies of this instruction.

4.0 PR INFORMATION STORAGE METHOD (PRISM)

The PRISM program gives the ICAPS user a means to store data files on a magnetic tape cartridge. A PROFGEN program option permits the operator to store environmental data, essentially a copy of what is written by PROFGEN to the Z999-ICAP:IM intermediate file, into a permanent save file. All save files created by PROFGEN in this manner have names ending in :PR. If BT data are routinely saved for ocean area analysis the limits of the system disk may be eventually exceeded. There is a finite amount of storage space on the disk, and a limit of 203 labels or filenames in the disk directory. To avoid violating these limits :PR files should be stored on tape when direct access is no longer required. PRISM facilitates this process by providing a structured method for storage and retrieval of :PR files. An important feature of the program is the directory it creates and maintains of the tape contents. The use of INPUT/OUTPUT or COPY commands to store data on tape would make the operator responsible for such bookkeeping. PRISM displays the director, figure 4-1, at the user's request. The directory lists file names, location on the tape (track and file number) and the data and geographic location of the data contained in each file. Up to 150 save files may be stored on a cartridge tape.

```
*****************************************************************

                          DIRECTORY
*****************************************************************

NUMBER OF ENTRIES:   20
NEXT AVAILABLE FILE:TRACK:    6:4

 FILENAME              FILE NO.  TRACK      LAT         LON       DATE

   1 AFTBT:PR                0       2      400N      16800W      1 181
   2 AG1DMJ:PR               0       3     5500N      17800W      1 181
   3 ASRAPM1:PR              4       3     3710N       4551W     15 479
   4 BT159LON:PR             1       2     4000N      15900E      1 181
   5 BTTWO:PR                0       4     1700N      15600E      1 181
   6 DROP3:PR                1       3     2600N      14100E      1 181
   7 FN26:PR                 4       4     3700N       1730E      1 180
   8 FNOC:PR                 1       4     5500N      15800W      1 181
   9 GEN:PR                  5       2     3710N       4551W      1 181
  10 JUL13:PR                2       2     2900N      14100E      1 181
  11 METRO:PR                2       3     5500N      16500W      1 181
  12 MF35:PR                 5       3        1N          1W      1 1 1
  13 NUKE:PR                 5       4     3000N       6000W      1 119
  14 PAC17S:PR               3       2     5500N      17800W      1 181
  15 PACJUN:PR               2       4     4000N      15000E      1 181
  16 T7BT:PR                 4       2     5500N      17600W      1 181
  17 TACFOR01:PR             6       2      840N       5124E     26 879
  18 TACFOR02:PR             6       3      840N       5124E     26 879
  19 TAWAIBT:PR              3       3     5500N      15600W      1 181
  20 TSCBT:PR                3       4     5500N      16100W      1 181
```

Figure 4-1. PRISM Tape File Directory Display.

5.0 OCEANIC DATA ANALYSIS (ODA) PACKAGE

5.1 INTRODUCTION

The Oceanic Data Analysis (ODA) package is a tool for a synoptic analysis of ocean thermal structure and acoustic properties. ODA stores, retrieves, and displays data from bathythermographs (BTs) within a given area. ODA promotes effective use of ASW resources by:

(1) helping the ICAPS user select representative BTs for processing into acoustic and tactical products;

(2) delineating boundaries between areas of different thermal and acoustic nature;

(3) providing the ASW decision maker with information needed to determine where, how many, and how frequently additional BTs should be deployed; and

(4) producing environmental analysis graphics suitable for tactical briefings and reconstructions.

BT data are entered into the ICAPS profile-generator model, PROFGEN. PROFGEN merges a historical surface-to-bottom depth/temperature/salinity (D/T/S) trace with the input depth/temperature data. PROFGEN calculates a total sound-speed profile from this composite trace and puts the information in an intermediate file for use by other programs in the ICAPS suite. If the user selects the ODA option, PROFGEN writes information to the ODA file in a format different from that of the intermediate file. In this manner, the file is developed for ensuing analysis. Since ODA processing does not alter the intermediate file, it does not interfere with other programs in the ICAPS.

The ODA package is a series of analysis/display techniques available to the operator. These techniques apply to measured and calculated oceanographic and acoustic characteristics of the environment. Analyses may be divided into four categories on the basis of: 1) temperature, 2) sound speed, 3) depth, and 4) gradient. Displays consist of: 1) tabular output, 2) point plots, and 3) profile traces. Input to the analysis/display functions comes from the ODA data file, either by direct retrieval or via intermediate calculations. The ODA package is organized in a step-by-step fashion that requires minimal operator keyboard input to direct the flow of the analysis. Hard copies may be made of all output displays appearing on the CRT screen. No analysis output is stored on the computer.

5.2 FILE DEVELOPMENT AND MAINTENANCE

BT data are introduced into the ODA data file via PROFGEN. A BT and its ancillary information are added to the ODA data file automatically when the user selects the ODA option. The hour of observations (four-digit number)

and a platform identifier (A for air or S for surface followed by a four-character alphanumeric string) must be added for ODA processing. The identifier of each platform should not only be unique but should allow other users to distinguish between data sets. The hull number of the ship or the tail number of an airplane could be used. These indexing parameters are required for information retrieval and file maintenance. A complete ODA data record consists of: time by day (1-31), hour (0000-2359), month (1-12), and year (00-99), position by latitude and longitude, platform identifier, number of data points in the BT and in the total profile, sonic layer depth, and the depth/temperature/sound-speed data points. The depth/temperature/sound-speed data points are stored in metric units.

The ODA data file may be built only by executing PROFGEN and selecting the ODA option as described above. If further ICAPS processing of BT data in the ODA data file is desired, that data must be retrieved and restored to the intermediate file. This transfer may be accomplished only by executing the RESTORE option in the ODA program. The user first selects option 4, Archive/Delete from the ODA package Option List. He then specifies the RESTORE option and identifies the BT he wants to process. The ODA data file entry is retrieved and the intermediate file is rebuilt. The ODA data file does not contain bottom loss classification. Therefore PROFGEN must be executed using the data placed in the intermediate file by the ODA RESTORE option to retrieve bottom loss classifications from the ICAPS data base. In this manner the intermediate file is made complete, and further processing of the data through other ICAPS programs may proceed.

Only one ODA data file exists on a disk pack. Initially the file is empty; it is constructed via operator input. Consequently, the geographic extent of the data file is determined by the user. The ODA data file cannot exceed 304 records. As the file approaches this limit, a warning message is displayed. If the limit is reached, no further input is allowed until space is freed from the data file.

All data regardless of age have some potential value. Thus, observations can be stored off-line on a cassette tape. Both manual and automatic operations are involved in the archive process. Manual operations include selecting a BT or set of BTs (and ancillary information) and inserting the tape into the QANTEX tape drive. Once annotated, the data are automatically written to tape in an indexed format. The index provides a ready reference to the contents and location of the data on the tape.

Regardless of the number of observations involved, the operator must specify those to be archived; there is no automatic archive based on time or availability of on-line storage space. Writing data to tape does not automatically eliminate it from the ODA data file. It is, therefore, possible to make several tapes using the same data, either for backup purposes or for mailing to another location. Off-line storage preserves the data for future climatological studies, as well as maintaining efficient operation of the ODA package.

After the data have been archived, they should be deleted from the ODA data file. Observations may be deleted singly or as a set by specifying a location, time or platform filter. Archive and delete are two separate functions; one may be performed without the other. The recommended procedure, however, is to first archive and then delete. In that way no data are lost; they may be recovered from tape at any time.

5.3 ANALYSIS PACKAGE

General

The ODA package allows the user to:

(1) define an area of interest;

(2) select BTs for review within this area, including:

- a. all observations,
- b. observations made within a specified time window,
- c. observations taken by a specific platform;

(3) select analysis/display techniques;

(4) archive/delete information from the data file;

(5) terminate analysis.

The operator can repeat any of the first four major functions listed above until he terminates the analysis. The operator enters an option to pass program control to the appropriate section of the ODA package. Functions 1-3 must be executed in order. However, once an option is successfully executed, the information is retained until that option is executed again. Selection of option 5 returns control to the operating system.

Area Definition

Prior to any oceanographic analysis, the operator must specify minimum and maximum latitudes and longitudes for an area. The smallest area that may

be defined is 2° by 2°; the largest, 20° by 20°. These scales provide a detailed view of a small area or a general view of a large area. Normal operations involve an area size somewhere in between. The area of interest may be a current operating area, a search area for a mission scenario, or an area of future interest. The size of the area can be adjusted depending on the need.

Regardless of the size of the area of interest, a look at the 20° x 20° area will yield information on data distribution. Subsequent paring down of the area allows the user to balance the number of observations and the area covered.

The area grid is displayed on the CRT screen using a Mercator projection. The display scale is based on the largest range in either the specified latitudes or longitudes. This technique yields the most accurate distribution of the observations within the grid. In the event that the input boundaries result in an unused portion of the CRT screen, the operator may expand the grid in the direction of the blank portion of the screen. At that point, the program divides the maximum number of raster units in the given direction equally between the minimum and maximum boundary limits, sacrificing true Mercator projection. An alternative is to redefine the area limits.

BT Selection

After defining the area of interest, the operator must review and select BTs for analysis. Review may encompass all observations in the defined area, or the observations may be further refined by specifying a time window or a platform identifier. Data of any time series of 90 days or less may be analyzed through selection of a time window. It is advisable to display no more than 30 days of data for analysis, since the ODA displays are intended to show a snapshot of ocean conditions at a point in time.

The platform filter may be used as a means of analyzing or eliminating the data from one particular source.

The selection process results in a BT locator chart (figure 5-1) and a tabular listing of important parameters (figure 5-2). The tabular listing includes: BT index number, BT logical record number, platform name, latitude, longitude, date, time, sonic layer depth (SLD), temperature at 200 m (T200), sea surface temperature (SST), and bottom depth (ZBOT). The BT index number (1-304) is assigned to a BT in the order of retrieval from the file. The index number is associated with a particular BT for the duration of the analysis.

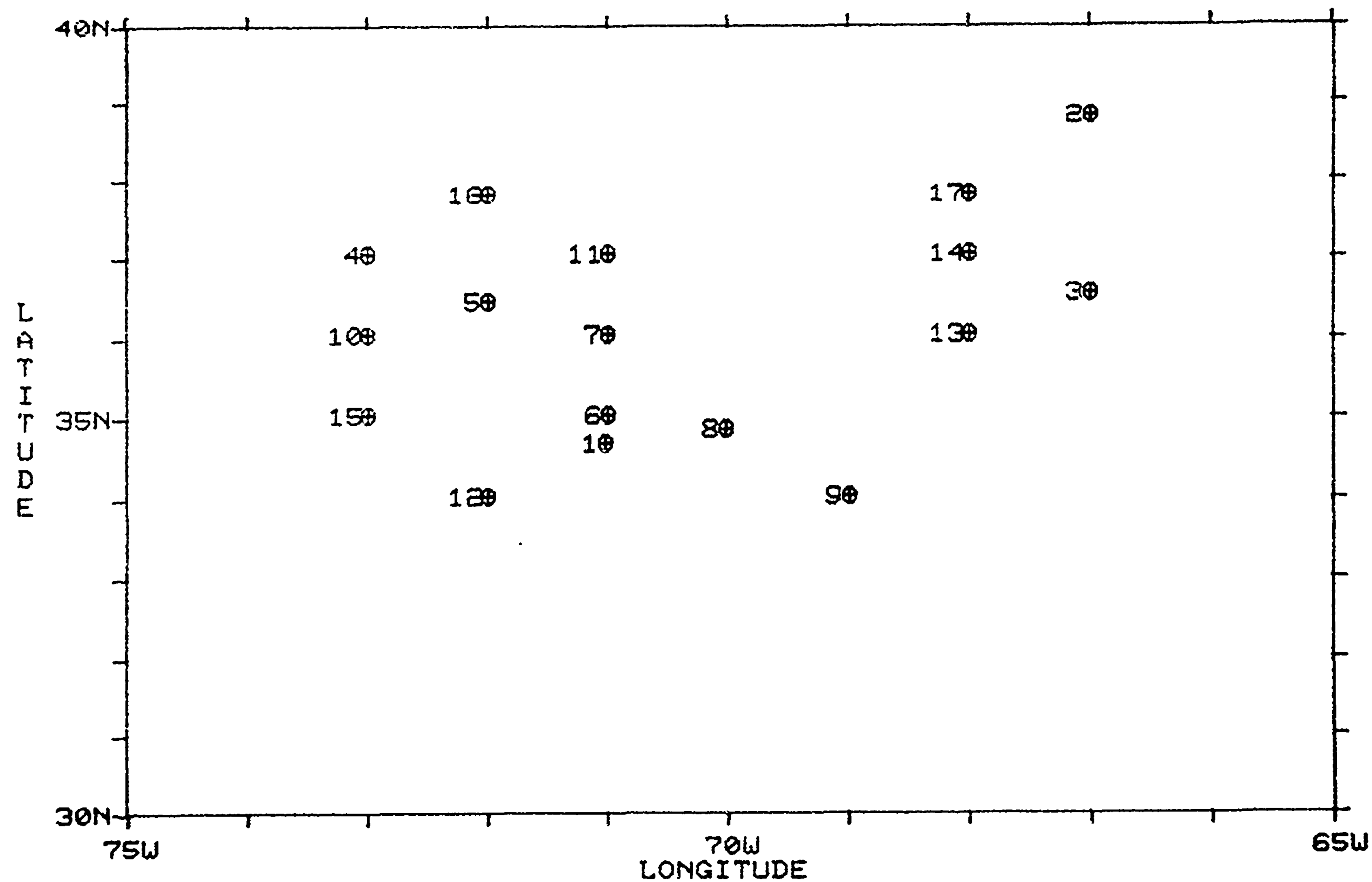


Figure 5-1. BT locator chart

OBSERVATION PERIOD = 22 DAYS.

INDEX	BT	NAME	LAT	LON	DATE			TIME	SLD	T200	SST	ZBOT
1	85	ACVN69	3440	-7101	24	4	77	24	645.	18.40	21.50	4800
2	86	SF1087	3845	-6700	22	4	77	759	51.	10.74	15.30	4600
3	87	SF1087	3630	-6700	23	4	77	1619	370.	18.26	18.50	4960
4	88	SF1087	3700	-7300	5	4	77	0	52.	9.39	16.90	3200
5	89	SDD964	3625	-7200	7	4	77	0	460.	18.24	18.30	4200
6	90	ACVN69	3500	-7100	11	4	77	0	560.	18.43	19.00	4600
7	91	ACVN69	3600	-7100	12	4	77	0	503.	18.26	19.70	4400
8	92	SDD964	3450	-7001	14	4	77	0	497.	18.40	19.70	5200
9	93	SDD964	3400	-6900	16	4	77	0	452.	18.26	18.70	5200
10	94	SF1087	3600	-7300	4	4	77	0	68.	19.04	23.80	3800
11	95	ACVN69	3700	-7100	13	4	77	2316	465.	18.26	18.60	4200
12	96	SDD964	3400	-7200	9	4	77	1251	515.	18.67	19.30	5000
13	97	ACVN69	3600	-6800	19	4	77	1502	470.	18.20	18.20	4800
14	98	ACVN69	3700	-6800	20	4	77	936	560.	18.36	18.40	4800
15	99	SF1087	3500	-7300	3	4	77	2156	32.	18.80	21.80	4330
16	100	SF1087	3745	-7200	6	4	77	1345	142.	9.96	12.20	3600
17	101	ACVN69	3745	-6800	21	4	77	111	45.	11.50	14.10	4600

Figure 5-2. Listing of BTs from three platforms

The BT locator chart (figure 5-1) serves as the backbone of the ODA package. This chart depicts the location of each BT by index number within the area. A descriptive label appears with the locator chart, identifying the information and time period involved.

The final step prior to analysis involves specifying the working BT data set, i.e., which of the reviewed BTs are to be included in the analysis. The operator may include all of the BTs currently under review, or exclude specific BTs from the data set.

Analysis

The analysis phase encompasses all data manipulation--retrieval and calculations--resulting in the various displays available in the ODA package. Retrieved data include: temperature, sound speed, bottom depth, depth excess, and SLD. Calculated data include: critical depth, depth excess, deep sound channel axis depth and thickness, in-layer and below-layer gradients, and interpolation of depth, temperature, or sound speed values not directly available. A list of the analysis/display functions can be found in table 5-1. The input, processing and output are provided for each of these functions.

Temperature Analysis

Temperature analysis may be performed on a BT data set or the corresponding surface-to-bottom (composite) profile. These two data groups may be displayed either as profiles or as geographic plots.

Geographic plots similar to the BT locator charts display temperatures at depths of interest determined by the user. Figure 5-3 shows the temperature observation at a depth of 200 m for each of the BTs presented in figure 5-1. The user may enter -1 to display the temperature at the sonic layer depth for each BT location on the chart.

A single-profile plot (figure 5-4), whether BT or total merged, lists the actual depth-temperature pairs plotted. The temperature and depth scales are also clearly marked on the plot. In the case of side-by-side plots (figure 5-5), the temperature scale is not labeled; however, the temperature minimum (TMIN) and the temperature maximum (TMAX) are given, as is the temperature interval between tick marks. Each profile is plotted on the same temperature scale, the left-hand limit being equal to TMIN and the right-hand limit TMAX. No tabular information is provided due to space limitations. If a single-profile

TABLE 5-1. ANALYSIS/DISPLAY FUNCTIONS

ANALYSIS/DISPLAY FUNCTION	INPUT: OPERATOR	INPUT: DATA FILE	PROCESSING	OUTPUT
BT location chart	Lat., lon. (platform, time)	Corresponding data records	All BTs within specified limits are retrieved from data file, their position on CRT grid calculated, and index numbers assigned in the order of retrieval	1) Point plot display of all BTs within limits, positions denoted by an index number. 2) Tabular listing of indexing and descriptive parameters
BT trace	Index no.	BT information	Retrieval of BT	BT trace on annotated grid; tabular listing
Multiple BT traces	Index no.	BT information	Retrieval of BT information, indexing and grid spacing calculations	Series of BT traces, abbreviated grid annotation
Temperature surface	Depth of interest (numeric or SLD)	Temperature information	Retrieval of temperature information as specified depth, interpolating when necessary	Point plot of temperature values at depth; tabular listing
Depth surface	Temperature of interest	Depth information	Retrieval of depth values at specified temperature, interpolating when necessary	Point plot of depth information at specified temperature; tabular listing
Temperature profile	Index no.	Merged profile information	Retrieval of total merged profile	Profile trace on annotated grid; tabular listing
Multiple temperature profiles	Index nos.	Merged profile information	Retrieval of merged profiles; indexing and grid spacing calculations	Series of profile traces, abbreviated grid annotation
Temperature trace or profile overlays	Choose BT or total profile; index nos.	BT or profile information	Retrieval of specified BTs or profiles, grid calculation, symbolic line representation calculations	Single grid, overlay of traces using different symbolic line images with reference table
Temperature differences	Two depth levels	Temperature information	Calculation of temperature differences between two levels, interpolate temperature information if not directly retrievable	Point plot of temperature differences; tabular listing
Depth difference	Two temperature levels	Depth information	Calculation of depth differences, interpolating when necessary	Point plot of depth differences tabular listing
Sound speed surface	Depth level (numeric or SLD)	Sound speed information	Retrieval of sound speed values, interpolating when necessary	Point plot of sound speed values at specified depth

TABLE 5-1. ANALYSIS/DISPLAY FUNCTIONS (Cont.)

ANALYSIS/DISPLAY FUNCTION	INPUT		PROCESSING	OUTPUT
	OPERATOR	DATA FILE		
Sound speed trace	Index no.	Sound speed information	Retrieval of sound speed trace corresponding to BT trace only	Near surface sound speed trace to bottom of BT on annotated grid; tabular listing
Sound speed profile	Index no.	Sound speed information	Retrieval of total sound speed profile	Sound speed profile on annotated grid with tabular listing
Multiple sound speed profiles	Index nos.	Sound speed information	Retrieval of indicated profiles, calculation of indexing and grid spacing parameters	Series of sound speed profiles, abbreviated grid annotation
Sound speed profile overlay	Index nos.	Sound speed information	Retrieval of specified SSPs, grid calculation	Single grid, overlay of profiles with references table
Sonic layer depth	Affirmative response to query	SLD information	Retrieval of SLD from data file	Point plot of SLD; tabular listing
In-layer gradient	Affirmative response to query	SLD, temperature information	Calculate ILG in °C/30 meters	Point plot of ILG temperature
Below layer gradient	Affirmative response to query	SLD, temperature information	Calculate BLG in °C/30 meters	Point plot of BLG temperature
Temperature gradient	Two depth levels	Temperature information	Calculation of gradient between two specified levels; interpolating as required if not directly retrievable	Point plot of temperature gradient; tabular listing
DSC axis depth and DSC thickness	Affirmative response to query	Sound speed profile information	Search for DSC from SLD downward and automatic calculation of channel thickness	1) Point plot of DSC axis depth with tabular listing 2) Point plot of DSC thickness with tabular listing
Critical depth and depth excess	Affirmative response to query	Sound speed profile information, SLD, bottom depth	Downward search from SLD to determine critical depth; depth excess calculated from bottom depth and critical depth	1) Point plot of critical depth with tabular listing 2) Point plot of depth excess with tabular listing
Vertical section	Select type of section; endpoints of section	BT, temperature profile, or sound speed profile information	Determine which points are within an epsilon of selected line; project onto line and compute position of points and spacing for display	Series of profiles (temperature or sound speed) along specified track, with accurate spacing representation

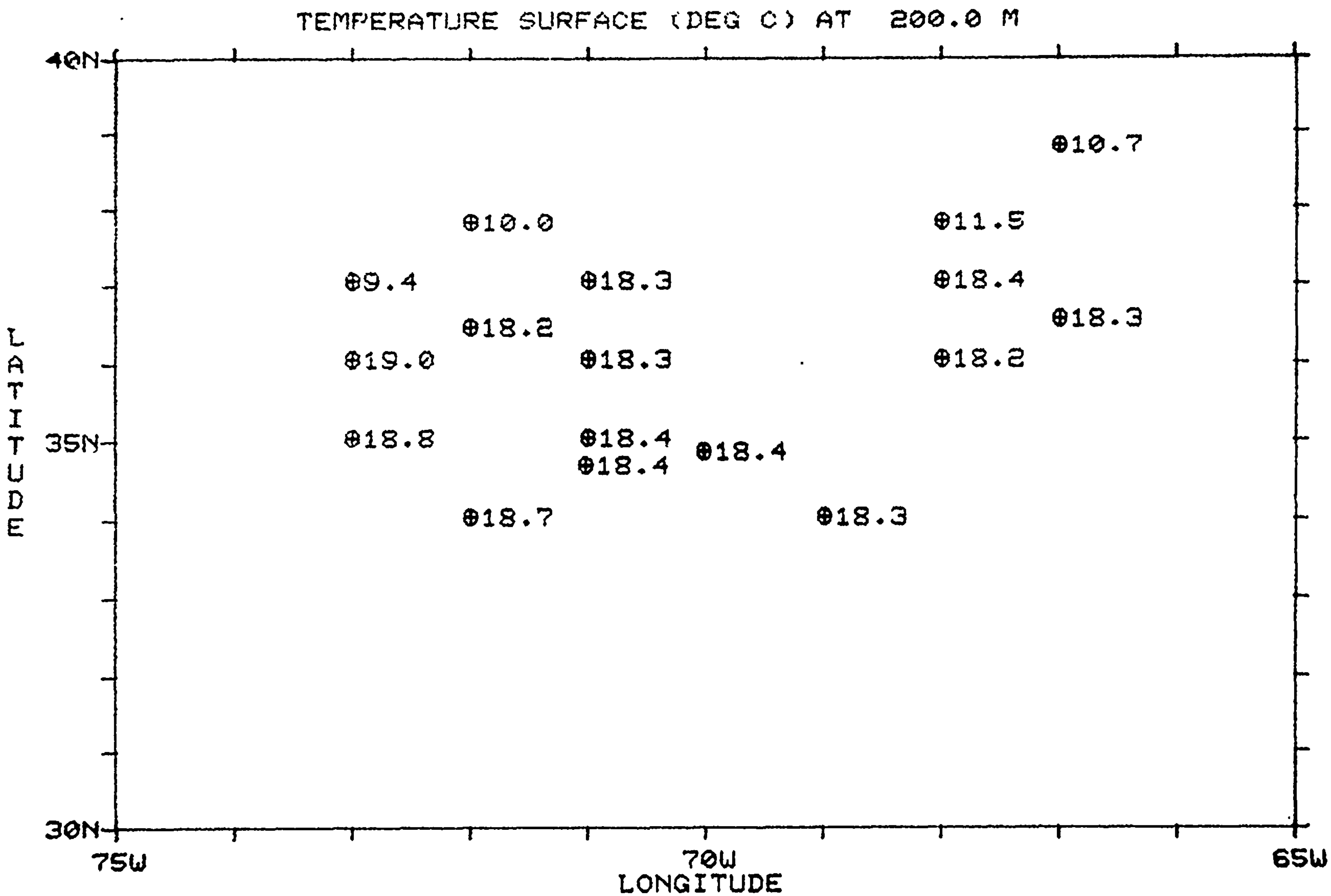


Figure 5-3. Temperature at 200 meters for selected BTs

DEPTH	TEMP
0.0	21.5
25.0	21.4
38.0	20.0
55.0	19.2
78.0	18.8
125.0	18.6
235.0	18.3
575.0	18.2
645.0	18.0
750.0	16.4
960.0	12.0

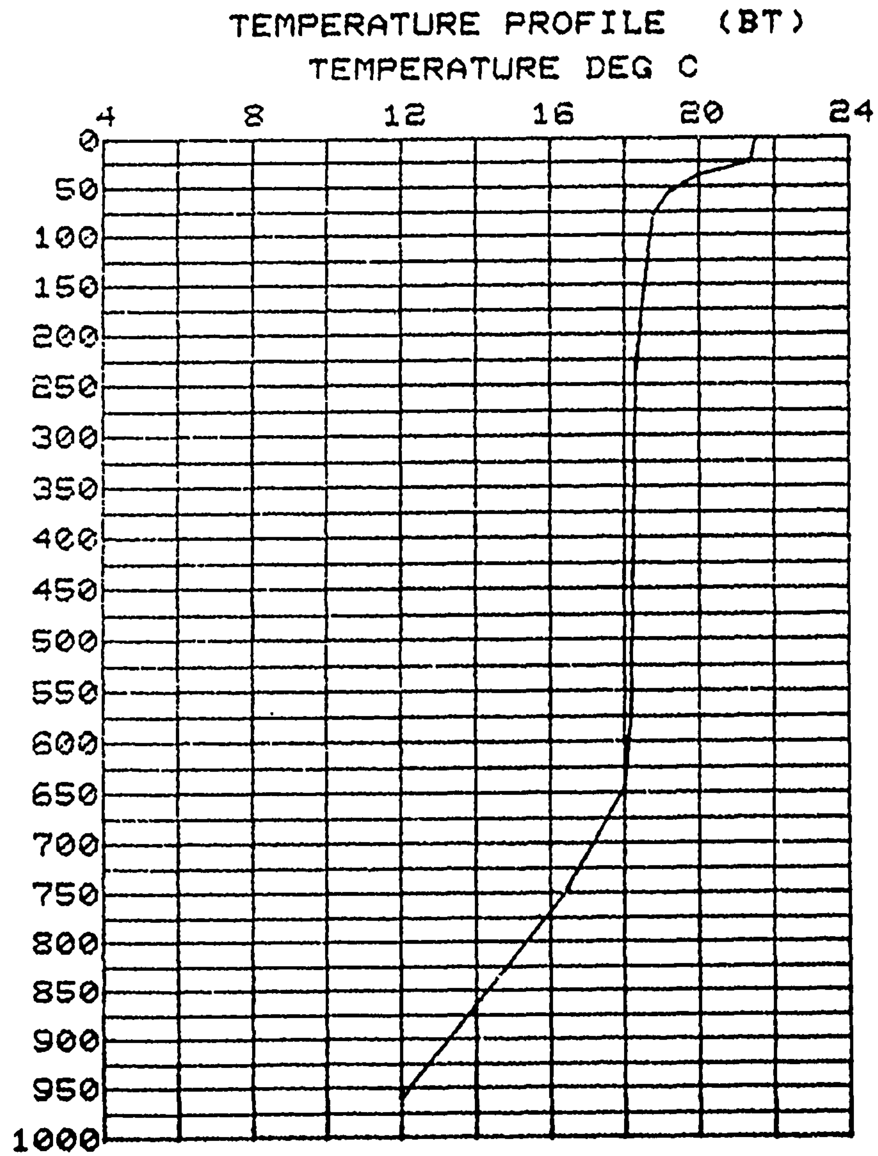


Figure 5-4. Single BT profile

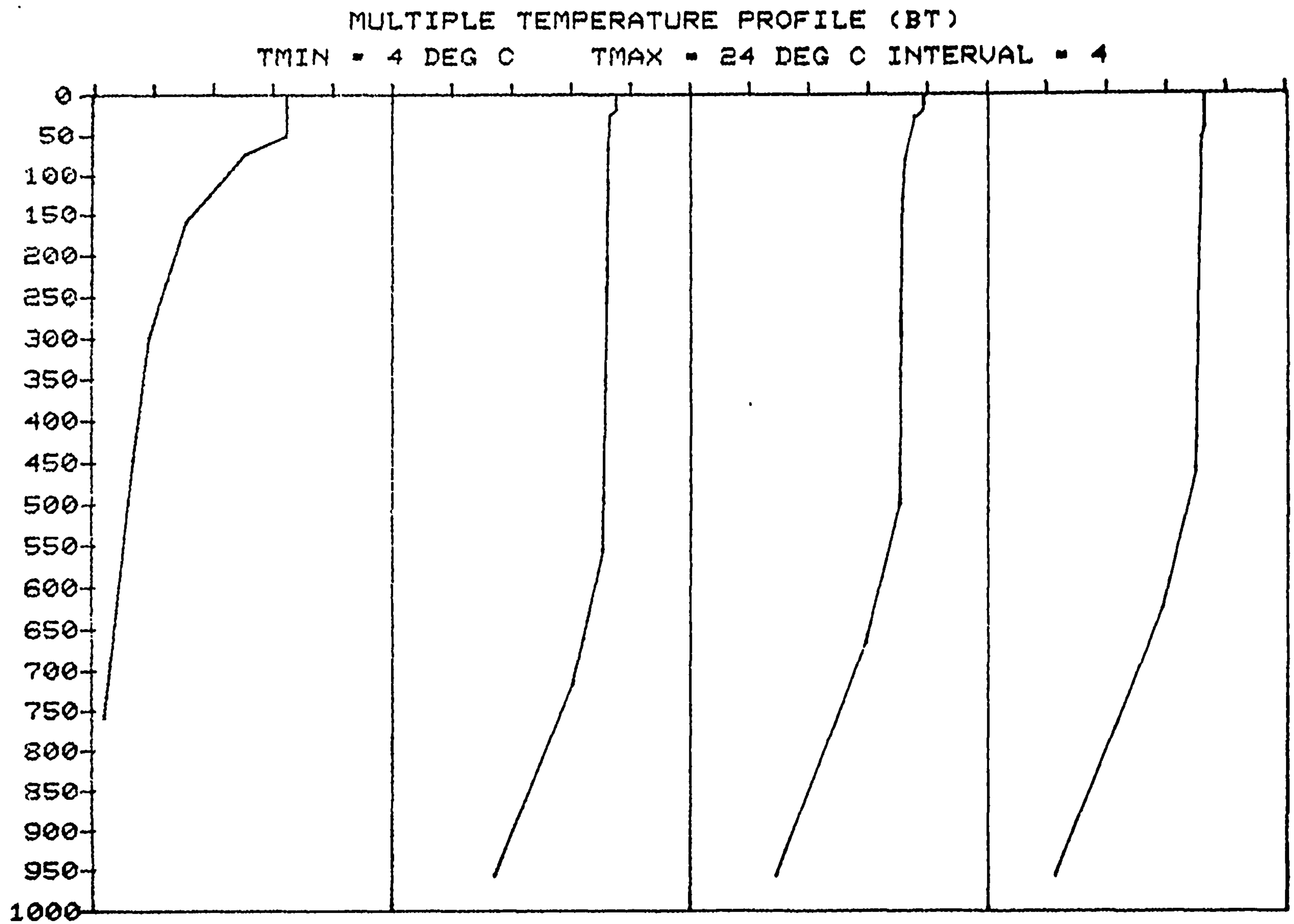


Figure 5-5. Multiple BT profiles

display of one of the side-by-side temperature profiles is desired, the user must identify the particular profile, recycle through the temperature analysis and select the single temperature display option.

One of the most important features of the temperature analysis is the ability to provide the information necessary to determine the water masses. A number of ODA products and displays can be used for water-mass analysis in the area of interest, but none show the water-mass differences as dramatically as the temperature profile overlays. The distinctive characteristics of water masses usually occur in the near-surface layers, thus the BT profile overlay plot normally exhibits the greatest detail. Figure 5-6 shows how water-mass separation can be determined from the displays.

The final form of temperature display is that of the vertical cross section. The user supplies the end points of a line in terms of latitude-longitude pairs inside the analysis area. All BTs within a certain distance of the line between those points are projected perpendicularly onto that line. The distance used to define the track envelope is always equal to 1/24 of the largest dimension (latitude or longitude) of the analysis area. Figure 5-7 indicates the track input for the section as well as the index numbers of the BTs which will be displayed. Figure 5-8 shows the BTs along the track. A similar display can be produced for composite temperature profiles. The location of the profile on the plot corresponds to its projected position on the track. The vertical section can be used to represent a ship's future course in order to predict the thermal pattern which will be encountered. The positions of water-mass boundaries along the transit route are also discernible for planning the BT drop schedule and to anticipate changes in acoustic characteristics.

Sound-Speed Analysis

The sound-speed analysis options are identical to those available in the temperature analysis section. Sound speed is plotted for any depth or for the SLD. As in temperature analysis, the user may specify a single sound-speed profile, multiple sound-speed profiles, or overlays of sound-speed profiles from BT or composite data sets.

Vertical sections for BT-derived sound speed and composite-profile sound speed may also be displayed. In vertical section analysis it is often helpful to view the temperature plots when interested in the shallow features and sound-speed plots when interested in deeper features. The sound-speed displays

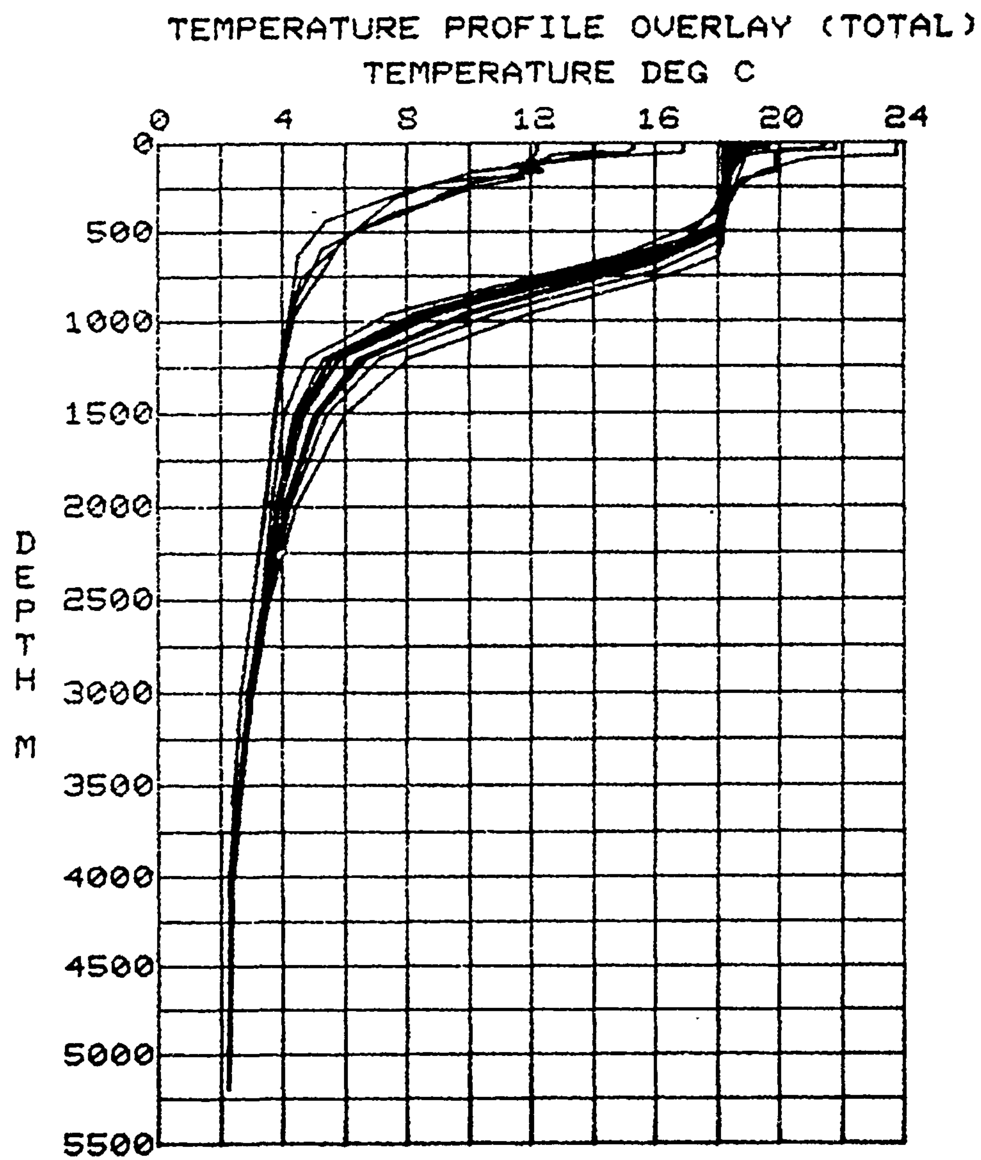


Figure 5-6. Multiple composite temperature profiles

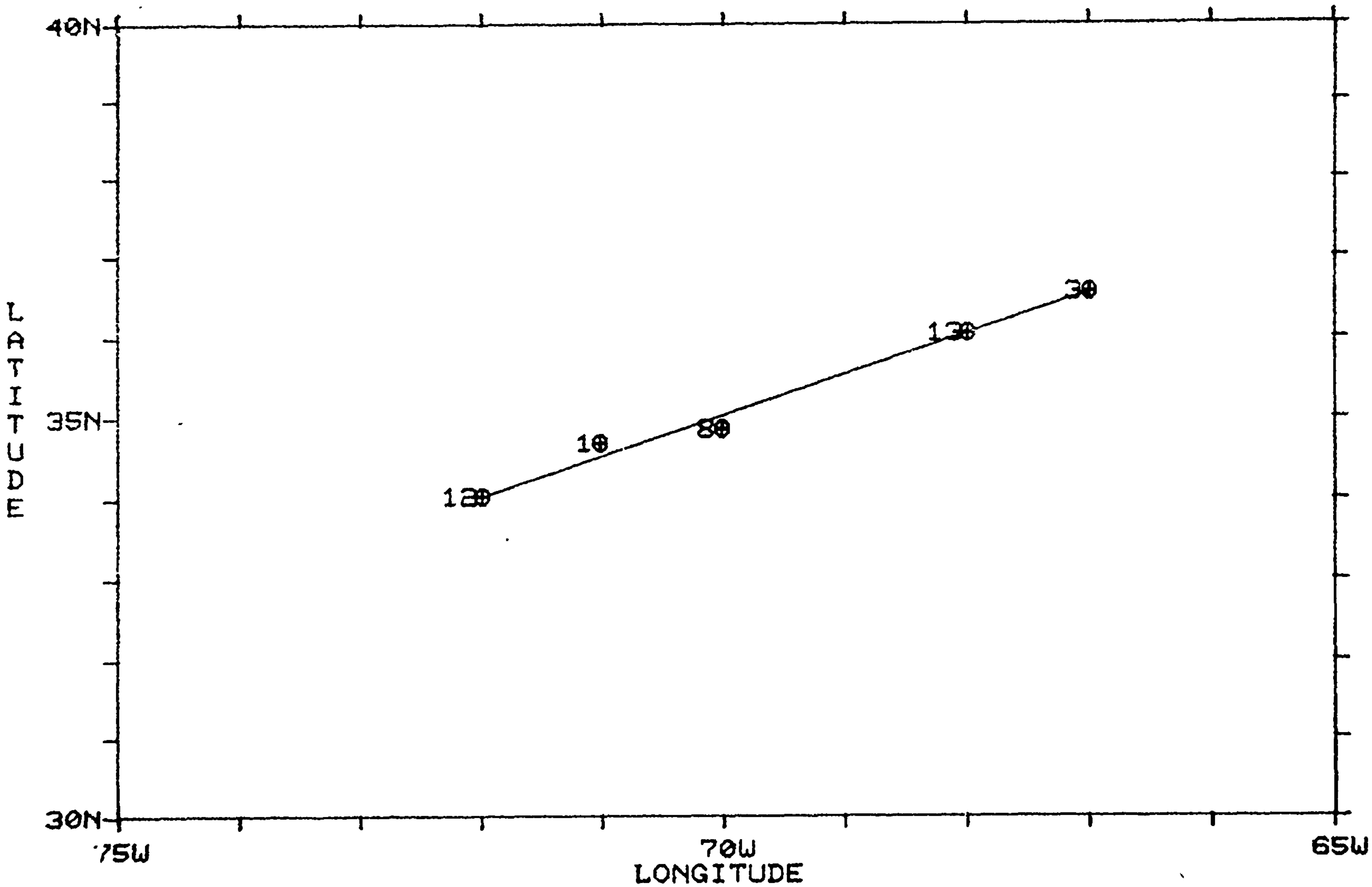


Figure 5-7. Display of track for vertical section

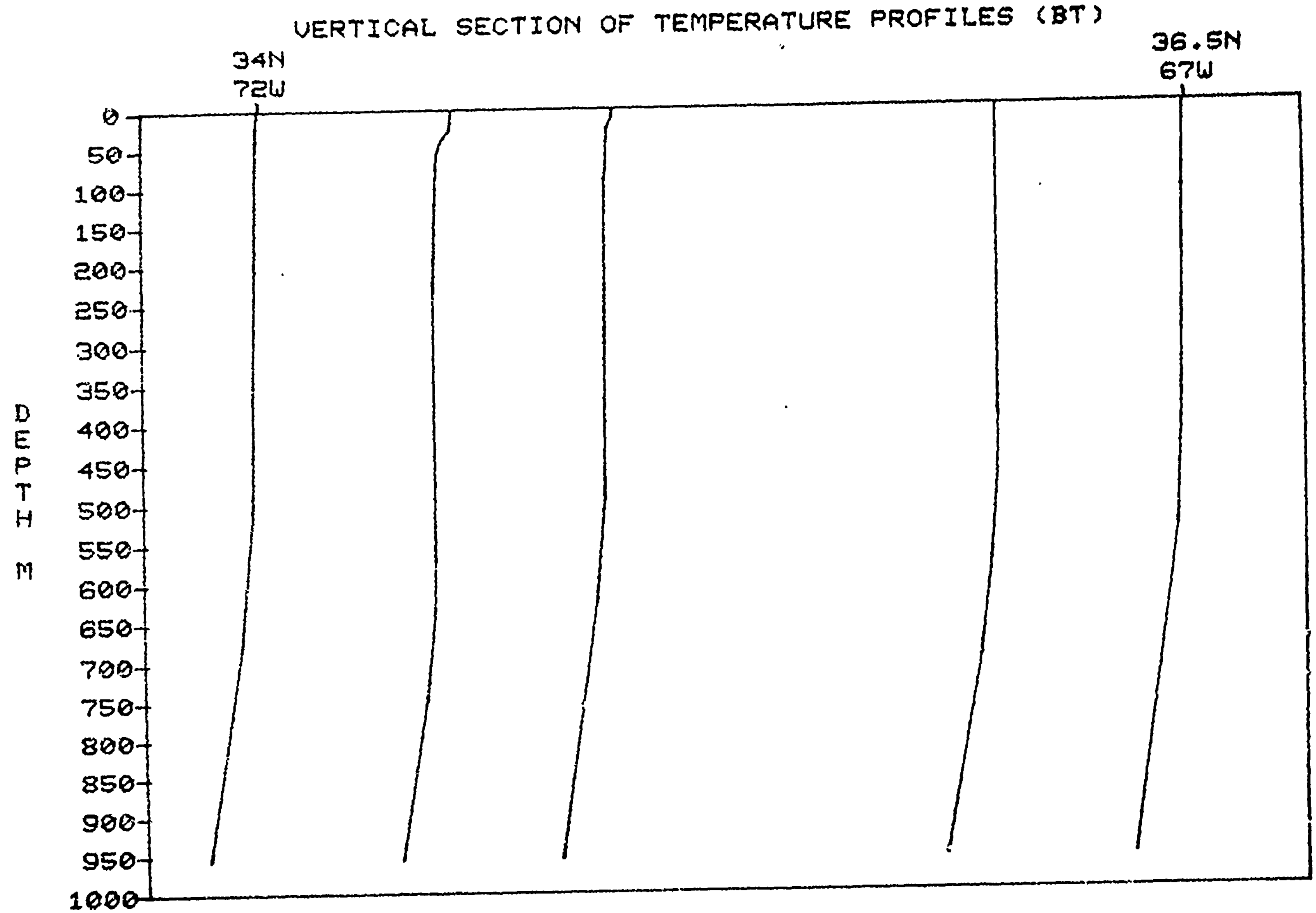


Figure 5-8. Vertical temperature (BT) section along the selected track

may be used to distinguish among different acoustic regimes and to get a qualitative idea of how acoustic signals may behave as they propagate from one part of the analysis area to another.

Depth Analysis

There are six depth displays, all in the form of geographic point plots. For a selected set of BTs associated with a BT-locator chart the user may request plots of the SLD; the depth of the deepest occurrence of an input temperature; the critical depth (defined as the depth below the sound channel axis at which the sound speed equals that at the SLD); the depth excess (the distance between the critical depth and the bottom); the depth of the deep sound channel axis; and the thickness of the deep sound channel. In the display of the depth of a specified temperature, the deepest occurrence is displayed. Where the same temperature occurs at more than one depth, the deepest occurrence is displayed followed by an I, indicating the presence of a temperature inversion.

The sonic layer depth provides a measure of how well the upper layers of the sea trap and transmit the acoustic energy. The point plot of SLD (figure 5-9) allows the user to observe whether the sonic layer depth is relatively constant in time or uniform in space. It is usually helpful to draw in contour lines by hand as an aid to interpretating such point plots.

The critical depth, as well as the depth excess, are important in order to determine whether bottom bounce or convergence-zone acoustic paths are present. The plot of depth excess shows specifically whether the water is deep enough to support convergence-zone propagation. For the depth excess plot, a positive value indicates that the water is deeper than the critical depth by the amount shown. A negative value indicates that the water is shallower than the extrapolated critical depth. The depth and thickness of the deep sound-channel axis indicate the operational usefulness of the sound channel. This information can be important in choosing depth settings for a towed array or sonobuoy.

Gradient Analysis

In-layer gradient (ILG) and below-layer gradient (BLG) are temperature gradients calculated to determine the extent to which acoustic energy is refracted in the vicinity of the SLD. The ILG is a measure of the ability of the surface duct to trap and conduct sound. The greater (more negative) the ILC and the

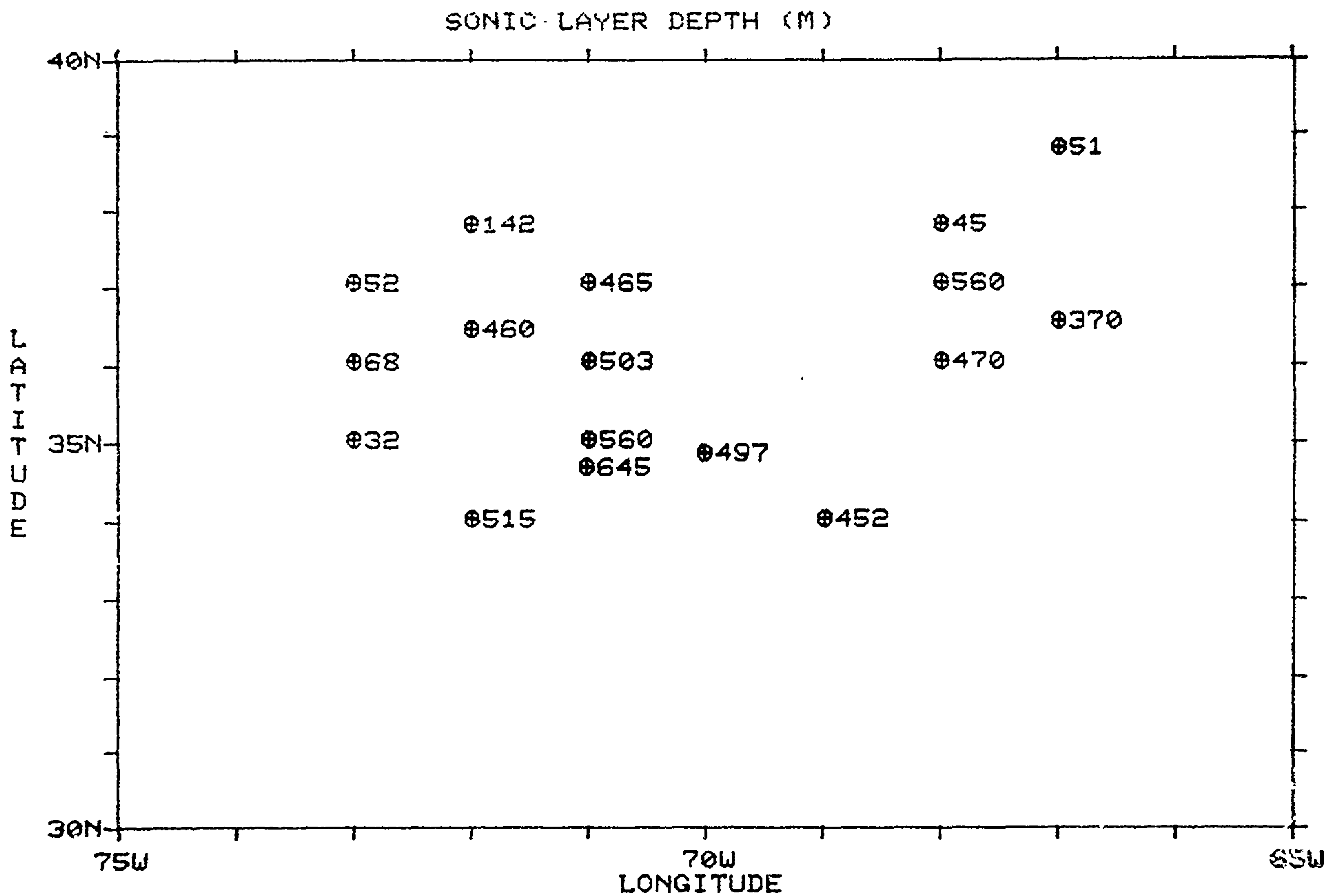


Figure 5-9. Point plot of SLD

deeper the SLD, the more sound energy is trapped in the layer, and the duct is said to be stronger. The BLG is a measure of direct path range below the layer. The stronger (more negative) the gradient, the greater is the refraction and consequently the shorter is the direct path range below the layer. ILG and BLG are displayed on area plots such as figure 5-10, which shows the ILG.

ILG and BLG are calculated for the working BT data set using the following algorithms:

$$ILG = \frac{30(T_{SLD} - T_{SFC})}{SLD}$$

$$BLG = \frac{30(T_L - T_{SLD})}{(L-SLD)}$$

where L is 30 meters below SLD and SFC denotes surface.

The temperature difference between two depths, depth difference between two temperatures, and the temperature gradient between two depths also may be plotted. The temperature gradient in the vicinity of a sensor depth may provide useful information about the behavior of sound at that level.

Sample Plotting and Analysis

Over the years, the experienced analyst develops techniques that permit rapid plotting and analysis of environmental data. The following suggestions are provided as an aid in developing these techniques. In the example given, only a part of the available data is used. Determining what data should be plotted depends upon what information is required for decision making. The choice of which plots to use and the method of analysis are the prerogative of the analyst.

The tabular listing (figure 5-2) is helpful in preparing the data for plotting. Water-mass determination can be made from the 200 m temperature. If the observations have been entered sequentially, it is possible to uncover position errors by computing the speed of advance (SOA) between successive observations.

During the plotting and analysis phases, the analyst must apply his knowledge of oceanography (1) to differentiate between real profile differences and those that result from errors, and (2) to relate profiles to the properties of mesoscale oceanic features of the area.

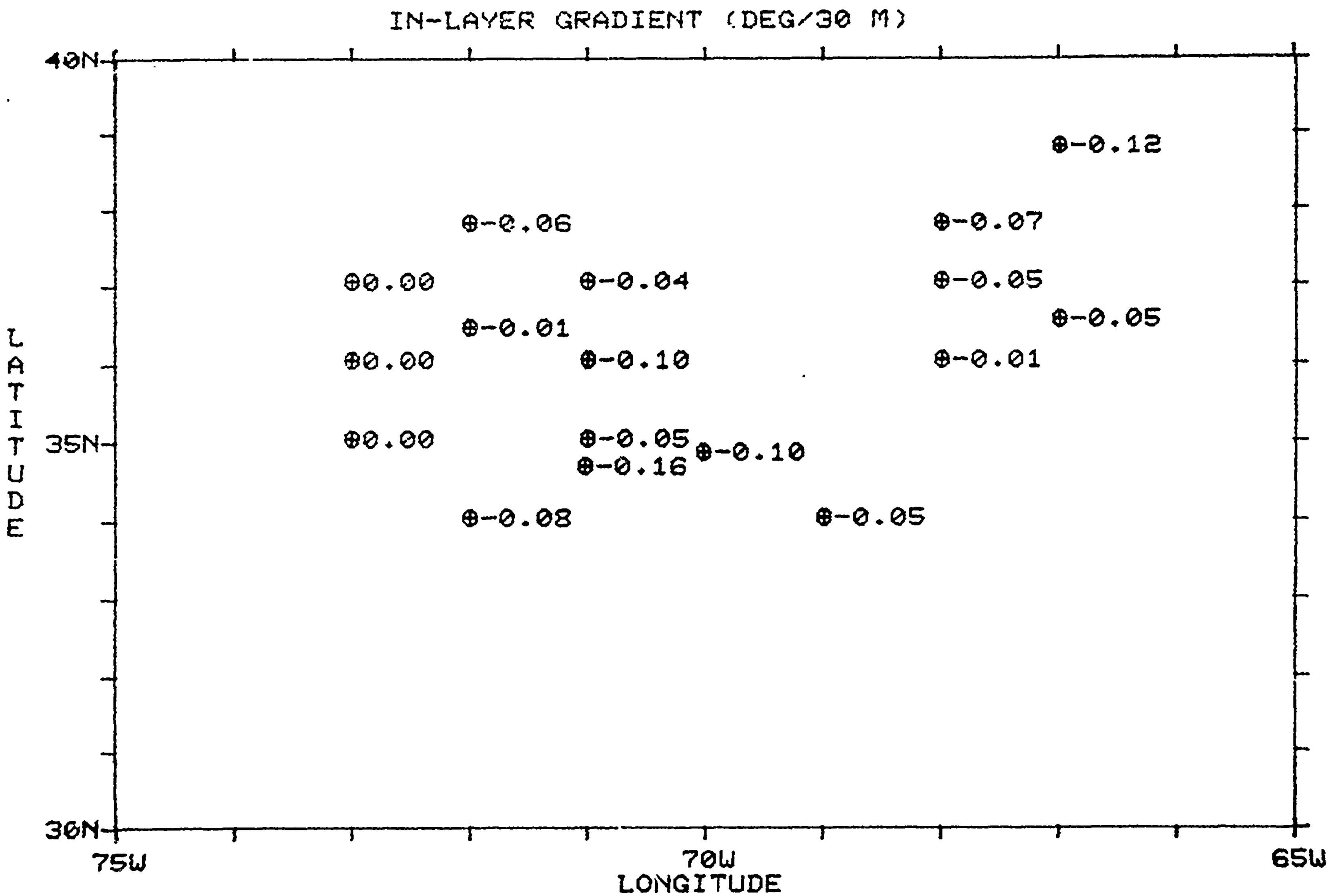


Figure 5-10. Point plot of in-layer gradient

Knowledge of oceanic processes is helpful in maintaining objectivity. In frontal zones, where water masses of different temperature-salinity characteristics occur, it is common for the warmer, less saline (and thus lighter) water to override the colder, more saline water with the result that the SLD may approach the surface.

Some of the possible displays which might be used to do a water-mass analysis are presented in the figures. The point plot showing the location of the BT field (figure 5-1) and the corresponding tabular output (figure 5-2) should be viewed first. The tabular values yield certain water-mass information:

(1) T200 indicates that BTs 2, 4, 16, and 17 are in a different water mass from the rest of the observations.

(2) SLD indicates that BTs 10 and 15 may also be in the same water mass as 2, 4, 16, and 17.

(3) The SST indicates that BTs 10 and 15 are not in the same water mass as 2, 4, 16, and 17.

The tabular values alone lead to the conclusion that there may be multiple water masses in the analysis area. The point plots of T200 and SLD presented in figures 3 and 9 support the water-mass indications from the table. A view of all the selected traces on a temperature profile overlay (figure 5-6) can be used to show that no false assumptions were made based on the point plots. In figure 5-6 it is clear that there is more than one water mass present in the selection set.

5.4 SUMMARY

The ODA program is a tool that automates oceanographic analysis. Because of the speed, accuracy and ease of data manipulation via ODA, the user can rapidly conduct quality analyses. Graphic aids are automatically produced for briefings and information packets. ODA provides a basis for development of sensor performance predictions representative of distinct water masses in the operating area. Through the use of ODA the knowledge of the acoustic environment is greatly enhanced. This knowledge can be directly translated into tactical decisions that give the user a distinct advantage by optimizing his use of the environment--for best sensor and weapons systems performance, or for concealment of forces.

6.0 GENERAL RAY TRACE (GENRAYT) MODEL

The GENRAYT program gives the user more flexibility in displaying sound ray paths and defining the acoustic environment than is available in other ICAPS models. The user may define a bottom topography and select particular sets or individual ray paths for display. GENRAYT is an alternate entry point for environmental data, provided the user has complete information, surface to bottom.

The user may specify, by initial angle, angle increment and number of angles, sound rays for display in a ray trace diagram. In this way transmission modes of particular interest can be emphasized. The effects of bottom topographic features on sound paths can be qualitatively examined by producing ray traces for an uneven bottom. Up to 50 range/depth points may be used to define a bathymetric profile. The sound speed profile governing the refraction of sound may either be retrieved from the intermediate file, Z999ICAP:IM, or be supplied by the user.

Environmental data defining the sound speed profile must be complete, surface to bottom. Either temperature/salinity/depth or sound speed/depth points are acceptable. Use of GENRAYT is the only way to avoid using salinity values from the data base atlases. GENRAYT, however, does not compute sonic layer depth or retrieve bottom loss classifications from atlas files. These values must be supplied by the user when the option to input environmental data is selected. GENRAYT stores user input environmental data in the intermediate file for access by the acoustic range prediction models.

Figure 6-1 shows the four "course of action," or program options available to the user. Figures 6-2 and 6-3 illustrate GENRAYT displays for operator-selected options. Input procedures are detailed in RP-24A (Volume I).

Option 1, RAYTRACE - produces a raytrace diagram (figure 6-2) using operator-specified rays;

Option 2, SVP Plot - yields a sound velocity profile graphic and enters the profile in the intermediate file;

Option 3, BOTTOM DEFINITION - allows the operator to define a range dependent bottom topography for use in ray tracing (figure 6-3);

Option 4, SVP INPUT - is used to enter sound velocity, or temperature and salinity, profiles when that data is available independent of PROFGEN. The process is illustrated in figure 6-1.

```
SELECT COURSE OF ACTION

1=RAYTRACE
2=SVP PLOT
3=BOTTOM DEFINITION
4=SVP INPUT
5=END OF JOB
 =4
UNITS OF DATA (1=ENGINEERING, 2=METRIC) =2
DATE(DD,MM,YY) =15,4,79
LATITUDE(DDMM) =3710
INS(1=N,2=S)=1
LONGITUDE(DDDMM) =4551
IEW(1=W,2=E) =1
NUMBER OF DATA POINTS IN PROFILE=10
INPUT DATA TYPE(1=DEPTH/TEMP/SALINITY,2=DEPTH/VELOCITY)=2
DEPTH/VELOCITY
METER//M/SEC
0,1514.9
140,1516.9
333,1513.4
405,1511.2
600,1505.2
1000,1490.1
1500,1491.9
2500,1505.7
4000,1527.5
5200,1548.7
```

Figure 6-1. GENRAYT SSP Input Display

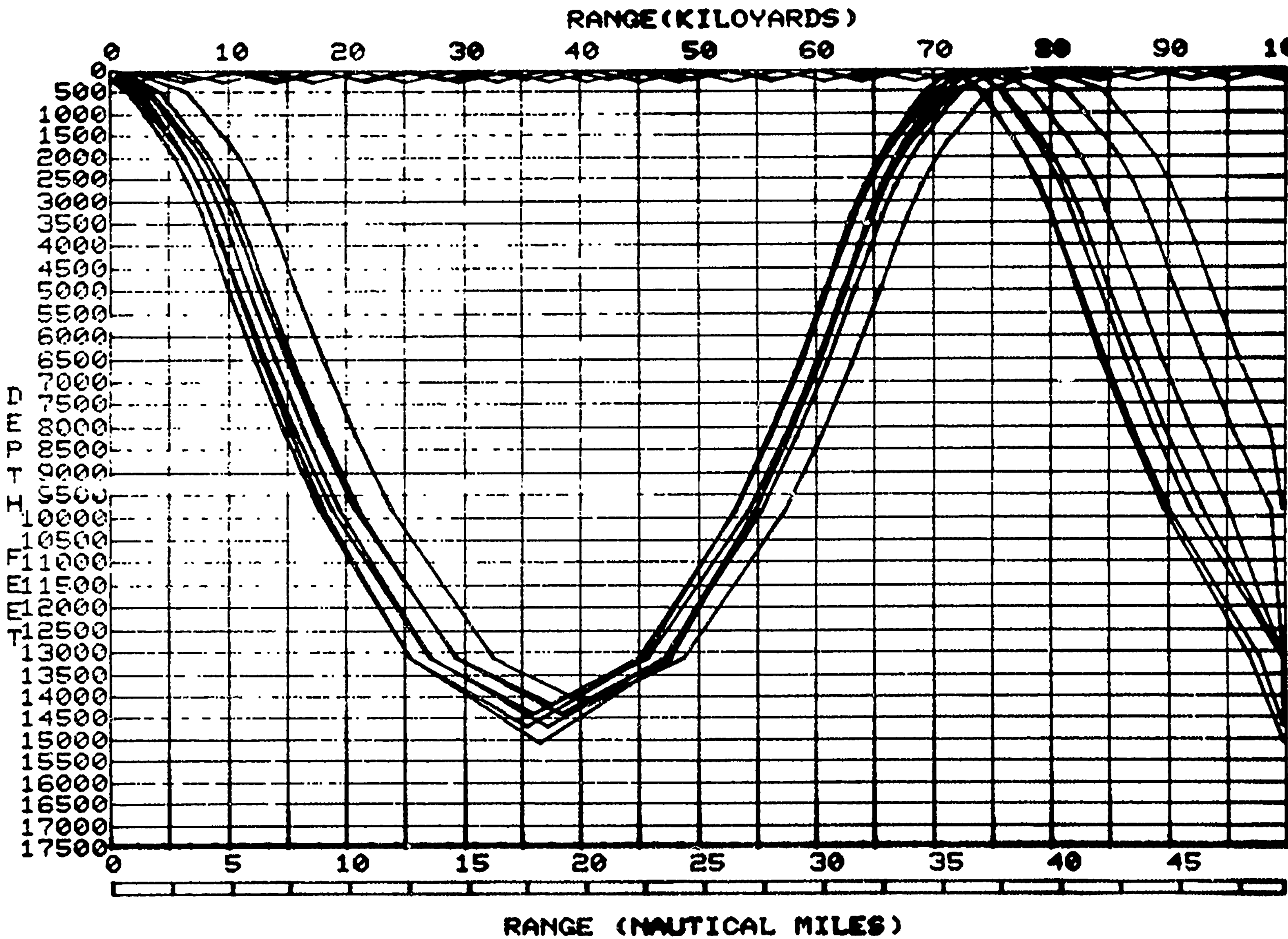


Figure 6-2. GENRAYT Raytrace Diagram

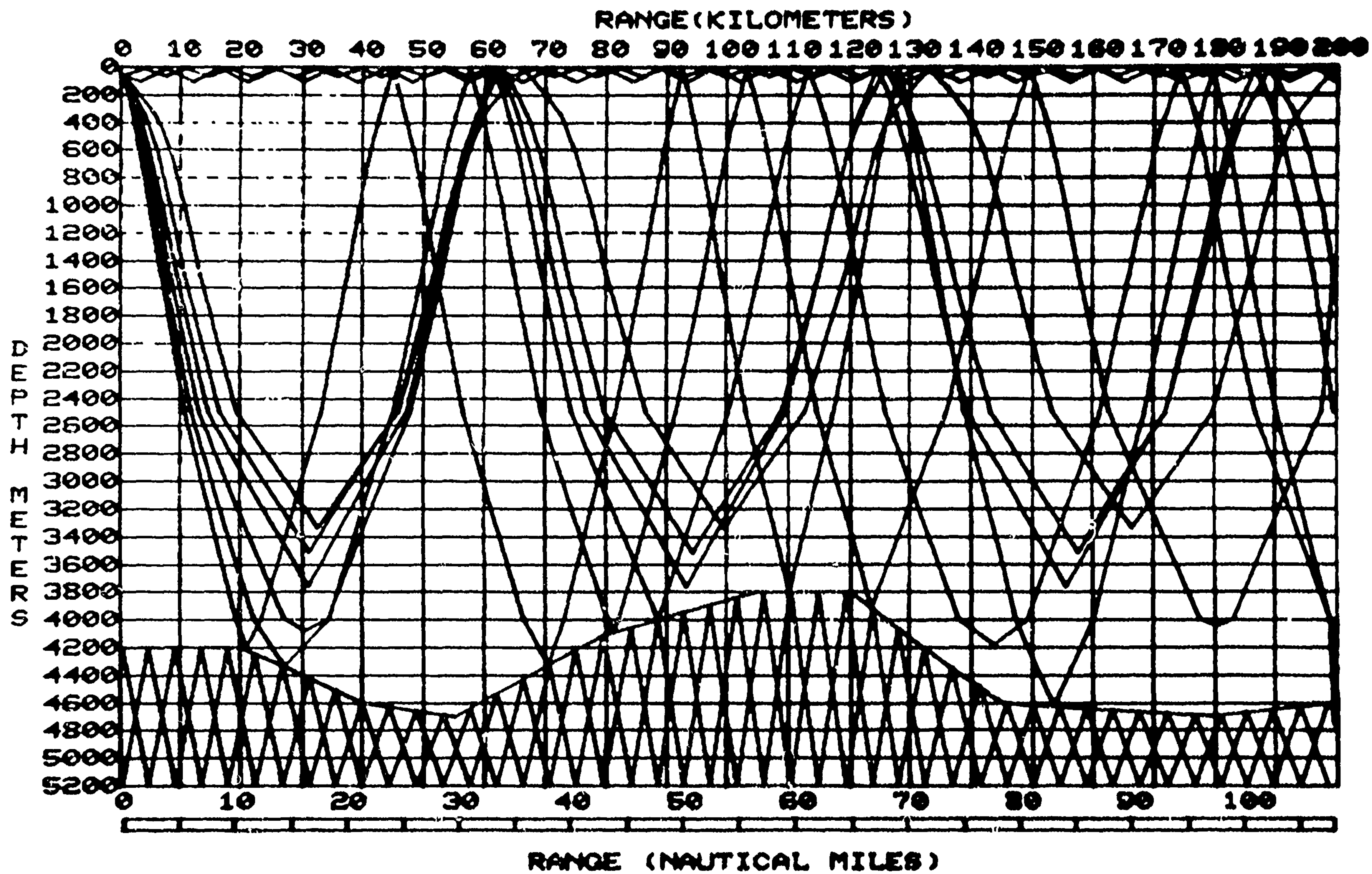


Figure 6-3. GENRAYT Bathymetric Display

7.0 FAST ASYMPTOTIC COHERENT TRANSMISSION (FACT) MODEL

7.1 GENERAL

The ICAPS FACT program is a version of the Navy Interim Standard Model for predicting transmission loss in an environment which is characterized by a flat bottom and a single sound speed profile. FACT is a composite ray theory model which computes transmission loss as a function of range and frequency, at user-defined source and receiver depths. The classical ray treatment in FACT is improved by higher order asymptotic corrections and the phased addition of selected paths. This approach yields a more complete model of diffraction and coherence effects to generate accurate long-range, low-frequency propagation loss predictions. FACT uses ray theory to calculate the sound propagation and propagation loss below the surface duct. Propagation calculations for the surface duct are based on Acoustical Meterological and Oceanographic Survey (AMOS) equations. The FACT model is considered more reliable in deep water than in a shallow water environment.

Losses due to volume attenuation (geometric spreading and absorption), boundary scattering, and absorption at the bottom are considered by the FACT model. Volume attenuation is a function of horizontal range and frequency. Refractive effects on spreading are modeled by slicing the ocean into horizontal layers in which the sound speed gradient is constant. Thus the sound speed profile is piecewise-linear; i.e., made up of straight line segments joined at the boundaries between layers. Within each layer, the rays trace arcs of circles. The model considers no losses through the ocean surface, but does include surface duct leakage loss at the sonic layer depth which is dependent on frequency and wave height. The ocean bottom is modeled as an imperfect reflector where losses are computed on the basis of ray grazing angle, frequency, and bottom province. To compute the loss due to these parameters, the Fleet Numerical Weather Central (FNWC) modified Bassett-Wolff bottom loss curves are used for frequencies below 1000 Hz. The Naval Oceanographic Office Navy Standard curves are used for frequencies of 100 Hz and above. Bottom loss increases with increasing bottom type index values and with frequency. Thus at high frequencies greater care must be taken in selecting the proper type.

7.2 PROGRAM FUNCTIONS

The operator supplies values for wave height, source and receiver depth (up to 3 pairs) and frequencies (up to 4), as well as the number of 1 kyd range points (up to 200) for which propagation loss calculations are to be made. Bottom province indexes, bottom depth, sonic layer depth and sound speed profile values are retrieved from the intermediate work file created by PROFGEN.

FACT output displays include a summary of program input parameters (Figure 7-1) and a sound speed profile (Figure 7-2). The propagation loss values calculated at each range point are presented in both tabular (Figure 7-3) and graphic (Figure 7-4) displays for each source-depth/receiver-depth/frequency combination. Propagation loss graphics may be displayed one per page, or two per page if more than one frequency is considered. If the one graphic per page option is chosen the propagation loss scale may be adjusted to enhance detail in the curve over a selected dB range. Ray trace graphics (Figure 7-5) illustrate the paths followed by sound emanating from the source. The ray traces extend to either 100 kyd or 200

kyd at the operator's option. The depth scale may be set to 20,000 ft, 10,000 ft, or 2,000 ft in order to preserve detail as the bottom depth decreases. If required, 30,000 ft and 40,000 ft depth scales are automatically selected. The FACT propagation loss versus range output is stored in the intermediate work file where it is accessed by LATRAN and other tactical models in the ICAPS software suite.

7.3 APPLICATIONS

The graphic propagation loss output described above, however, contributes directly to the user's understanding of how the environment impacts on the performance of his sensors. A line drawn across the propagation loss graph at the figure of merit (FOM) of the sensor cuts the propagation loss curve at the limits of 50% probability of detection coverage. In this manner the median detection range (MDR), convergence zone range (CZR), and convergence zone width (CZW) can be determined and appropriate tactics designed.

The ray trace graphics help the analyst picture what is happening acoustically in the water; what modes of transmission are in effect, where shadow zones exist, and so forth. The information presented provides clues to why the propagation loss curve has a certain form, which modes prevail at different ranges, and what receiver depth settings are best.

```
FACT INPUT PARAMETERS

      DATE =  4 / 15 / 79             LAT = 3710 N        LONG =  4551 W

NO. OF OBSERVED BT POINTS =   8
BT INPUT UNITS = 1 (1=METRIC,2=ENGLISH)
NO. OF SOUND-VELOCITY PROFILE POINTS = 19
NO. OF RANGE POINTS = 200
SONIC LAYER DEPTH (FT) =  459
WAVE HEIGHT (FT) =    5

NO. OF FREQUENCIES = 4
FREQUENCY (HZ)        BOTTOM PROVINCE
--------------        ---------------
       50
      150
      300
     1500

NO. OF SOURCE-RECEIVER PAIRS = 3
SOURCE DEPTH (FT)      RECEIVER DEPTH (FT)
-----------------      -------------------
        60                     60
       500                     60
       500                   1000
```

Figure 7-1. FACT Input Summary

15 APR 79
3710 N 4551 W
SONIC LAYER = 459 FT

VELOCITY	DEPTH
4970.28	0.
4976.09	361.
4976.67	459.
4967.72	919.
4965.14	1093.
4957.77	1247.
4957.99	1329.
4952.63	1493.
4938.30	1969.
4908.21	2625.
4888.88	3281.
4886.16	3937.
4894.52	4921.
4916.12	6562.
4939.86	8202.
4962.68	9843.
5011.61	13123.
5069.23	16404.
5080.87	17060.

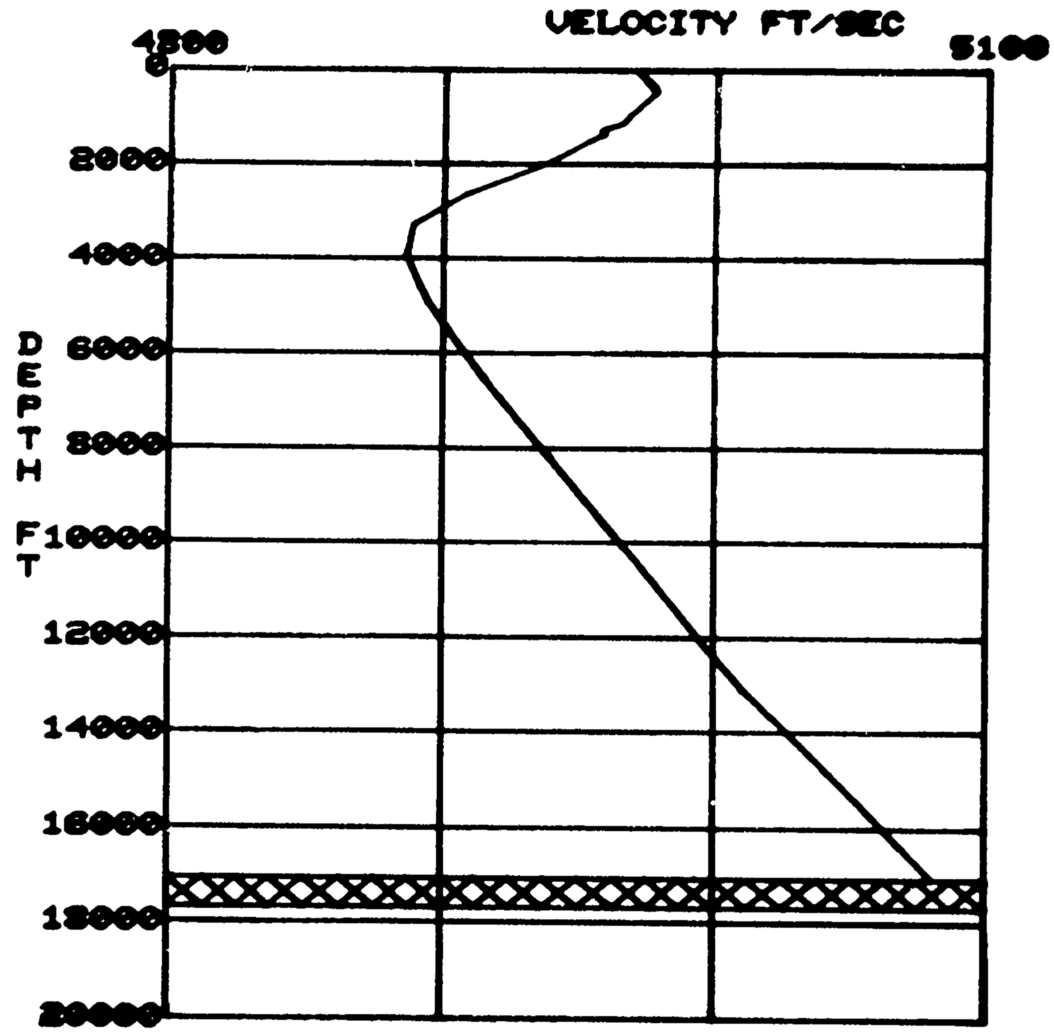


Figure 7-2. FACT Sound Speed Profile

PROPAGATION-LOSS VALUES

DATE = 4 / 15 / 79 LAT = 3710 N LONG = 4551 W

WAVE HEIGHT........ 5 FT
SONIC LAYER DEPTH.. 450 FT

SOURCE DEPTH... 500 FT
RECEIVER DEPTH. 60 FT
FREQUENCY...... 300 HZ

RANGE (KYDS)	1	2	3	4	5	6	7	8	9	10
1	60.4	65.3	68.3	70.7	73.0	75.4	78.0	81.3	84.3	84.8
11	85.3	85.7	86.0	86.3	86.6	86.8	86.9	87.1	87.2	87.3
21	87.5	87.6	87.7	87.8	88.0	88.1	88.1	88.2	88.2	88.2
31	88.3	88.3	88.3	88.3	88.3	88.5	88.7	89.0	89.3	89.5
41	89.8	90.1	90.4	90.6	90.9	91.2	91.5	91.8	92.1	92.4
51	92.7	93.0	93.3	93.6	93.9	94.2	94.6	94.9	95.2	95.5
61	95.9	96.2	95.0	75.0	79.8	81.4	74.8	80.2	81.4	84.0
71	84.8	85.6	86.3	87.1	87.9	88.7	89.2	89.6	90.1	90.5
81	91.0	91.5	92.0	92.5	93.0	93.6	94.1	94.8	95.4	96.2
91	97.0	97.9	98.9	100.2	100.3	100.4	100.5	100.5	100.6	100.7
101	100.8	100.8	100.9	101.0	101.0	101.1	101.2	101.3	101.4	101.5
111	101.7	101.8	102.0	102.2	102.3	102.5	102.7	102.8	103.0	103.2
121	103.3	103.5	103.7	103.9	104.1	104.2	104.4	104.6	95.2	90.1
131	85.4	83.1	83.1	84.4	85.2	85.8	87.3	87.7	89.6	90.0
141	90.3	90.7	91.0	91.4	91.7	92.1	92.4	92.8	93.1	93.5
151	93.9	94.2	94.6	95.0	95.4	95.9	96.3	96.8	97.3	97.9
161	98.4	98.9	99.2	99.6	99.9	100.3	100.7	101.1	101.6	102.1
171	102.6	103.1	103.7	104.3	105.1	105.9	106.9	108.1	109.7	110.6
181	110.8	110.9	111.1	111.2	111.4	111.5	111.7	110.5	110.6	110.7
191	110.9	111.0	111.2	110.3	91.2	85.8	88.1	83.1	86.9	87.8

Figure 7-3. Tabular Propagation Loss Display

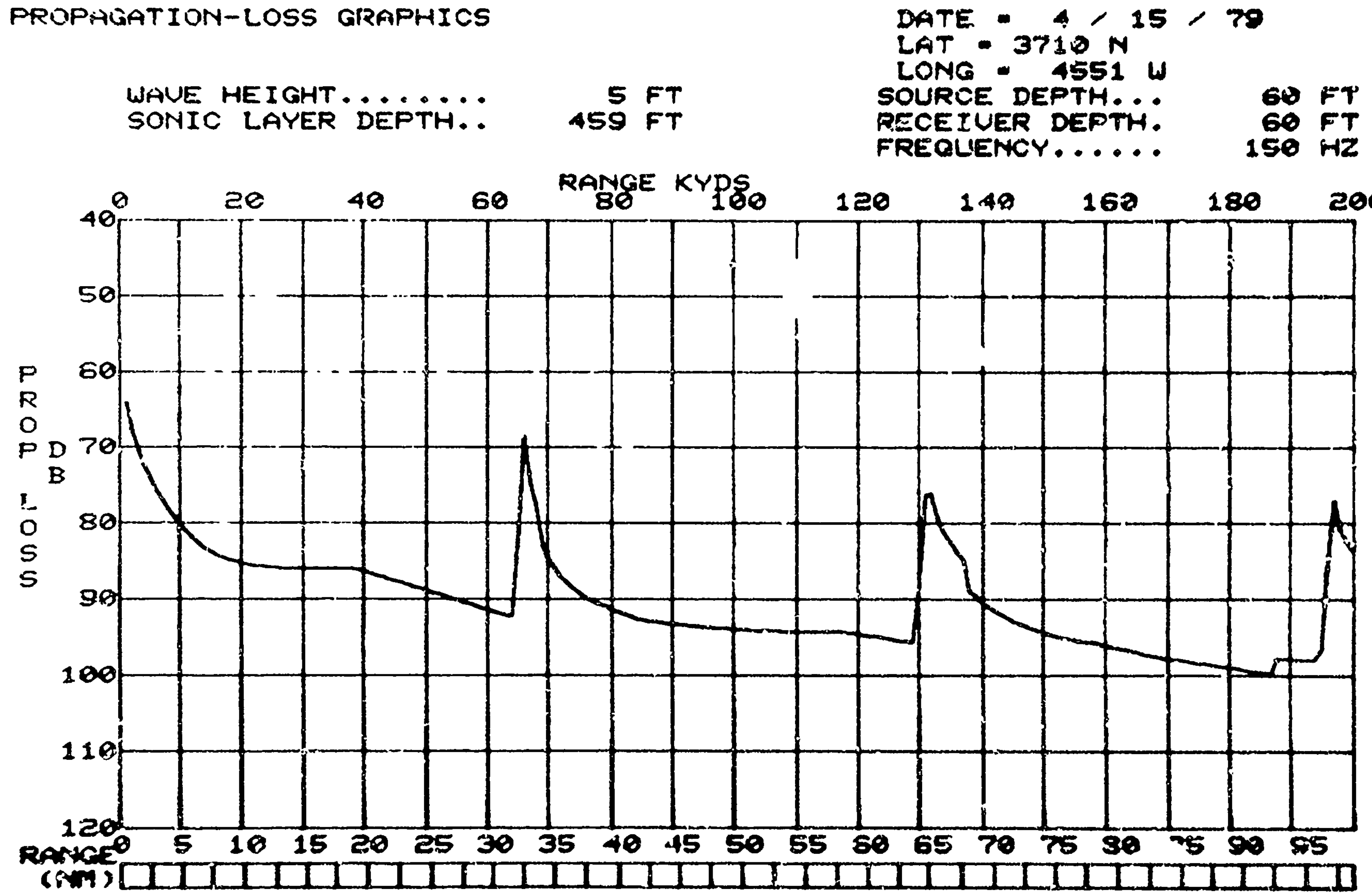


Figure 7-4. FACT Propagation Loss Curve

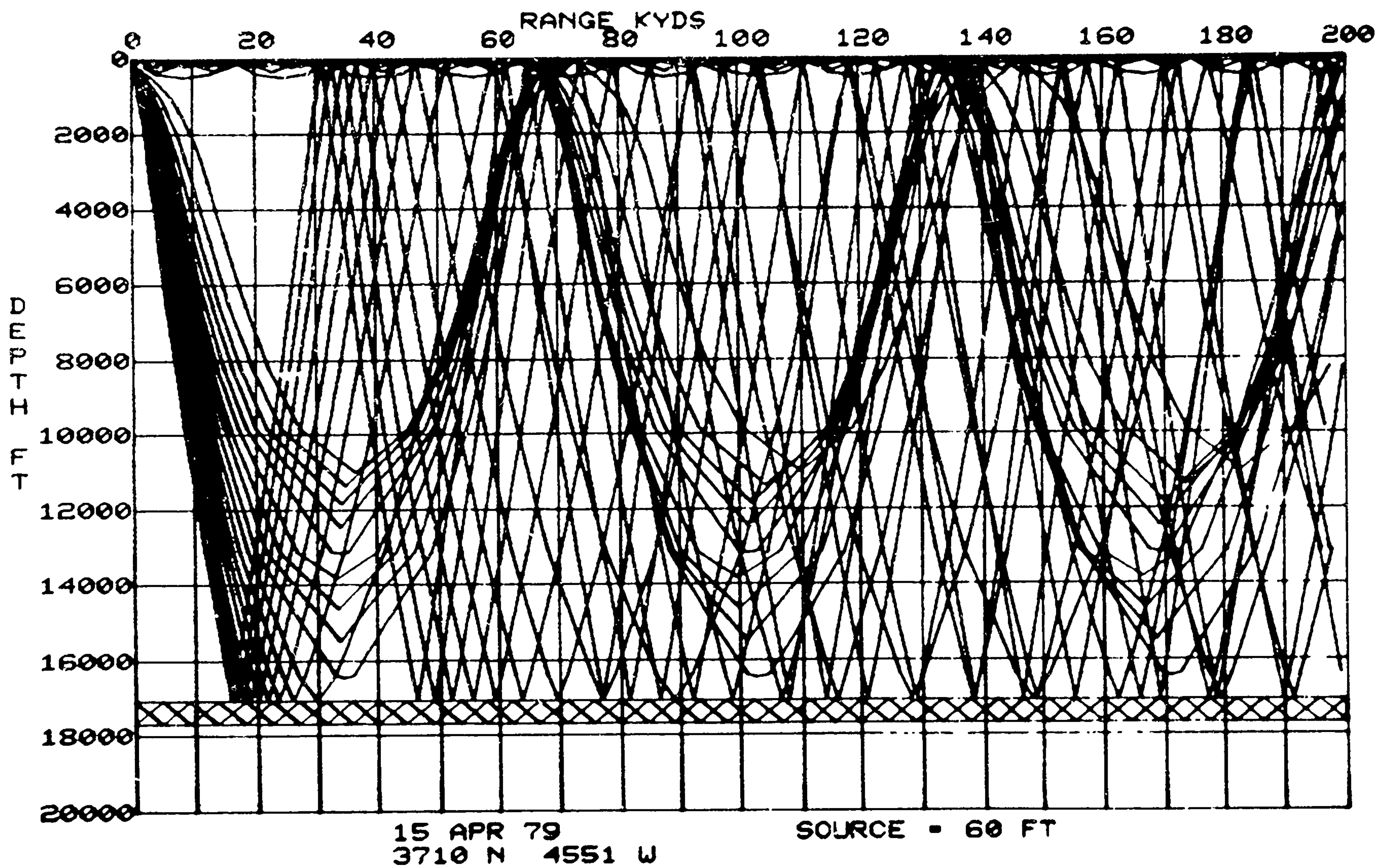


Figure 7-5. FACT Ray Trace

8.0 INTERMEDIATE FILE Z999ICAP:IM (ICAPFILE) CONTENTS DISPLAY

When restarting ICAPS, the operator may wish to know what is contained in the existing intermediate file, Z999ICAP:IM. To avoid rerunning PROFGEN and executing FACTGRAF:OL, the user can run ICAPFILE and get a summary (figure 8-1) of Z999ICAP:IM contents. Key information is displayed to assist the user in deciding whether the existing propagation loss information is adequate for his purposes, whether he should save the contents of Z999ICAP:IM in a permanent file, or whether he needs to make a new run.

```
INTERMEDIATE FILE Z999ICAP:IM

                              PROFILE:

DATE = 11 / 11 / 81                 LAT = 3318 N        LONG =  6918 W
NO. OF OBSERVED BT POINTS =  10
BT INPUT POINTS = 2 (1=METRIC,2=ENGLISH)
NO. OF SOUND-VELOCITY PROFILE POINTS =  22
SONIC LAYER DEPTH (FT) =  350
SONIC LAYER DEPTH (MT) =  106
LOW FREQUENCY BOTTOM TYPE =
HIGH FREQUENCY BOTTOM TYPE =
----------------------------------------------------------------------

                              FACT:

SONIC LAYER DEPTH (FT) =  350
WAVE  HEIGHT (FT) =  5
NO. OF RANGE POINTS =  10
NO. OF  FREQUENCIES =1
FREQUENCY (HZ)        BOTTOM PROVINCE
--------------        ---------------
     100

NO. OF SOURCE-RECEIVER PAIRS = 1
SOURCE DEPTH (FT)      RECEIVER DEPTH (FT)
-----------------      -------------------
      250                   1000
```

Figure 8-1. ICAPFILE Z999ICAP:IM Contents Summary Display

9.0 COMPACTED ASRAP (ASRAPC)

9.1 GENERAL

Compacted ASRAP (ASRAPC) is designed to condense propagation loss data into an abbreviated message form for rapid teletype transmission. The format (figure 9-1) eliminates the need for the user to graphically interpret propagation loss data in order to extract tactically useful information. It also provides a standard format for ASRAP data that is familiar to all users. A complete description of the format is given in section 9.2.

From the ASRAPC data format the mission planner may obtain such information as: Median Detection Range (MDR), Convergence Zone Range (CZR), and Convergence Zone Width (CZW). Probability of detection at all ranges within the MDR is greater than .50. If a Convergence Zone mode is present, the tactician needs to know at what intervals it occurs about the source. The horizontal width of the CZ, where at least a 50% probability of detection exists, is also important in the design of search patterns. The chances of detecting signals via Bottom Bounce mode is not usually critical to choosing the most appropriate tactic, but mission planners often like to have such added information to aid in tactical considerations. From the standpoint of trying to predict its existence or quality, Bottom Bounce is the most difficult transmission mode for the Fast Asymptotic Coherent Transmission (FACT) model to handle. One reason is that FACT assumes the ocean bottom is flat and homogenous with respect to reflectivity characteristics. This assumption limits the tactical usefulness of Bottom Bounce range values predicted by FACT.

ASRAPC displays the same sensor performance information as ASRAPC message transmittals from Fleet Numerical Oceanography Center. The format used is as close as practicable to that of the message product. However, no environmental data (depth, temperature, sound velocity) are included. The purpose of the ASRAPC product is to allow ICAPS users to readily support units in company with familiar sensor performance predictions. The effort required to construct the message on one end, and to interpret it on the other, is minimized.

Primary input to ASRAPC is the propagation loss data created by the ICAPS FACT program. ASRAPC permits the selection of a range of FOMs. The user indicates the range over which FOM may vary and an increment. Although output for a single FOM may be selected, this practice is not encouraged. Changes in sonar equation parameters or tactics may dictate the need for more than one FOM. Using several FOMs gives the user an appreciation of how small changes in FOM can alter detection ranges.

9.2 FORMAT DESCRIPTION

The header of the ASRAPC display (Figure 9-1) lists the source depth, receiver depth, and frequency used as input to the FACT propagation loss model. Below the header are four columns of data. The FOM column lists the Figure(s) of Merit for which the detection range information was computed. Median Detection Range (MDR) for each FOM are listed in the column labeled "M". Range increments are .5 nmi (1 kyd). Ranges outside the display capability, .5 nmi to 99.5 nmi, are indicated by the messages:

```
ASRAPC FOR3710N  4551W
SOURCE AT     60.0   RECIEVER AT     60.0
      FREQ    50.0

FOM        M       B            C
 60      LESS
 62      LESS
 64      LESS
 66      LESS
 68       0.5
 70       0.5
 72       0.5
 74       0.5
 76       1.0
 78       1.0
 80       1.0    11/ 1
 82       1.5     8/-         33/ 1/ 1
 84       1.5     7/14        33/ 1/ 1
 86       2.0     6/18        33/ 1/ 1
 88       2.0     6/24        32/ 2/ 2
```

Figure 9-1. ASRAPC Sensor Performance Display

"LESS" - MDR is less than .5 nmi
"****" - MDR lies between 99.5 nmi and 125 nmi
"GRTR" - MDR is 125 nmi or greater.

Column "B" indicates the ranges where the probability of detection by bottom bounce mode exceeds 50%. The value to the left of the slash (/) mark indicate the range at which bottom bounce takes effect, the inner edge of the region where bottom bounce detections are encountered. Values to the right of the slash (/) mark indicate the width of the region. Resolution is to the nearest whole nmi. The "B" column may also contain the characters:

"*" range or width values exceed the maximum number of spaces allowed (3);
"-" it is impossible to determine the inner edge of the bottom bounce region, as when that region is imbedded in the CZ path.

The first set of numbers encountered in the "C" column specifies the inner edge of the zone where detection by CZ mode exceeds 50%. The second number indicates the width of the CZ annulus. The final number represents the number of CZ annuli, out to 125 nmi, for which probability of detection exceeds 50% at the FOM indicated. Ranges are given to the nearest whole nmi. The following characters may also appear:

"*" range to the first CZ exceeds 99, or the annulus width or number of useful CZs exceeds 9, depending on where it is printed;
"-" dimensions of the CZ are impossible to define, as where they are superimposed on other transmission paths.

10.0 LATERAL RANGE (LATRAN) MODEL

LATRAN uses propagation loss information generated by FACT to compute passive lateral range curves. These curves, which describe how probability of detection varies with range, result from solutions of the passive sonar equation:

$$SE = SL - PL - AN - RD$$

where SE is signal excess, SL is source level, PL is propagation loss, AN is ambient noise, RD is recognition diffential (detection threshold), and the units are dB re 1 μPa. By definition, SE = 0 and PL = FOM (figure of merit) when the probability of detection (POD) is 50%. Thus, the passive sonar equation is also written:

$$FOM = SL - AN - RD$$

The operator supplies terms on the right-hand side of this equation so that FOM is computed directly. The operator also supplies the program with a value for the standard deviation (sigma) of the FOM, which determines the change in FOM required to produce probabilities of detection other than 50%.

Care taken in determining the values of the required input parameters, using the best available sources of information, is reflected in the accuracy of the results. AN is a critical factor in acoustic detection and one of the most difficult to evaluate. Appropriate values are found in tables based on shipping density (the dominant contributor at low frequencies), and sea state. Appendix B contains charts, tables, and instruction for determining AN in this manner. Direct measurement using calibrated instruments is the recommended procedure provided that the measurements are made close in time and space to the tactical applications.

SL is a characteristic of the target and is frequency-dependent. Acoustic signatures (narrow frequency band noise created by vessels' auxiliary and propulsion machinery) and source levels for different types and classes of threat submarines are found in appropriate intelligence publications.

RD, like the FOM, is defined in relation to a 50% probability of detection. Traditionally, RD is the amount by which the acoustic signal exceeds the background noise when the signal's presence is detected by the human ear 50% of the time. Modern signal processing equipment presenting a visual representation of the signal outmodes this definition. More properly, RD represents the detection threshold at the 50% probability level. Detection threshold is determined by the design characteristics and condition of the equipment without reference to the amount of experience or alertness of the operator.

Variability in the parameters described above, which enter the computation of the FOM, lead to a similar variability in the FOM. The actual values of these parameters may, at any particular time and location, be greater or less than the estimated values used in the expression for FOM. The values used are, in effect, the averages obtained from a large number of measurements made under controlled conditions. The resulting estimate for the FOM is therefore a statistical average, and experimental evidence suggests that the actual values are distributed in a bell-shaped (Gaussian) curve around that average. The standard deviation, or sigma, of the FOM indicates how steep the bell is, or how much confidence there is in the

value used. Appropriate values for the sigma of FOM are selected as follows:

- Use a sigma of 6 dB if ambient noise measurements are available and submarine type and speed (source level) are known;
- Use a sigma of 8 dB if ambient noise is estimated by the methods in Appendix B and submarine type is known or speed is known to within 3 knots;
- Use a sigma of 10 dB if ambient noise is estimated as in Appendix B and submarine type or speed in unknown.

Regardless of the sigma value selected, the propagation loss, and hence range, for 50% POD is unchanged (Figure 10-1). The different sigmas indicate the amount of departure in signal excess from FOM required for a given change in probability of detection.

The lateral range curves are an interpretation of the propagation loss curves in terms of probability of detection. The usefulness of the LATRAN product lies in its providing a goal-oriented measure of performance. LATRAN displays graphics of probability of detection, as illustrated in Figure 10-2, for source/receiver depth/frequency combinations selected by the operator from those considered in the FACT model. The display includes all LATRAN input parameters and information identifying the case.

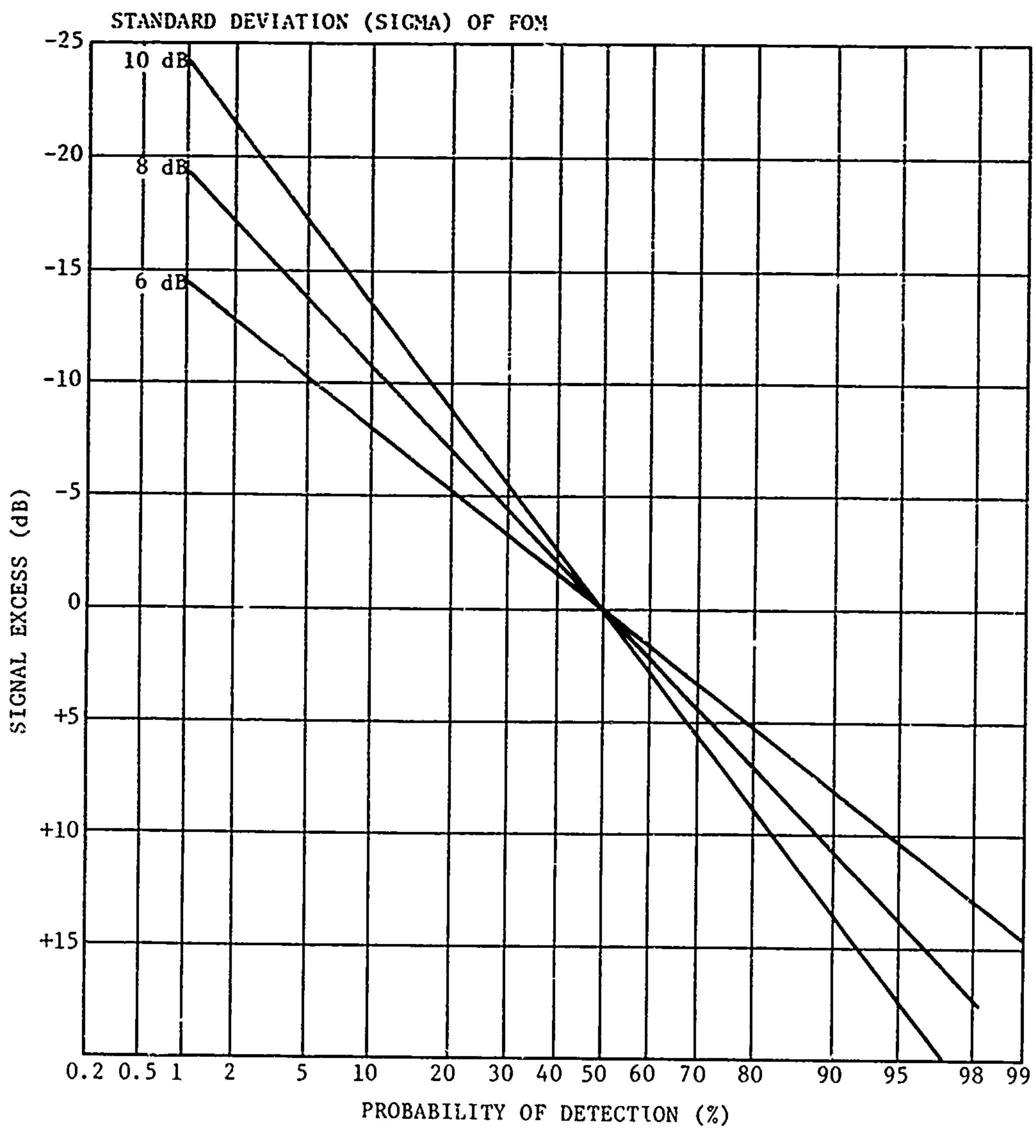


Figure 10-1. Signal Excess Probability of Detection Graph

LATERAL-RANGE-CURVE GRAPHICS

DATE = 4 / 15 / 79
LAT = 3710 N LONG = 4551 W

SOURCE DEPTH = 60 FT RECEIVER DEPTH = 60 FT
SOURCE LEVEL = 160 DB SIGMA FOM = 8 FREQUENCY = 150 HZ
AMBIENT NOISE = 80 DB RECOG. DIFF. = 0 DB FOM = 80

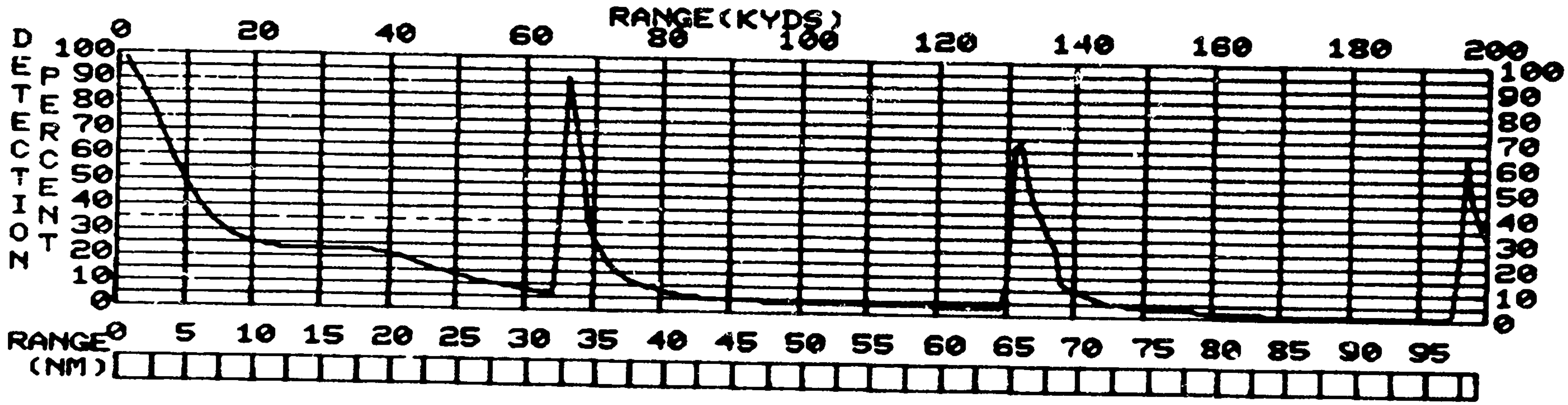


Figure 10-2. Lateral Range Curve

11.0 SHIP HELICOPTER ACTIVE RANGE PREDICTION SYSTEM (SHARPS) MODEL

SHARPS is an active propagation loss model which computes 50% probability of detection ranges for surface ship hull-mounted and variable depth sonar (VDS) systems, and helicopter dipping sonars. It is appropriate for use in ocean areas that are characterized by a single sound speed profile and a single depth. The Navy Interim Surface Ship Sonar Prediction Model II (NISSM II), incorporating ray tracing techniques and empirical formulas based on the AMOS (Acoustic Meteorological and Oceanographic Survey) equations, is used to calculate the sonar range predictions.

Range predictions based on a 50% probability of single-ping detection by an unalerted operator are provided for the following sonars using average equipment operating parameters:

SGS-39
SQS-41
SQS-26 (steel)
SQS-26 (rubber dome - OM)
SQS-23
SQS-23
SQS-35 VDS
AQS-13

In all cases, the in-layer range (ILR) is defined as the range to a target submarine at a depth of 60 ft, and below-layer range (BLR) is the range to a target at its "best depth" to avoid detection (sonic layer depth plus 200 ft). A hull-mounted sonar transducer depth of 20 ft is used in the propagation loss calculations.

Input parameters include wave height (used to calculate self noise), bottom type, volume and layer scattering coefficients, wind speed (for calculating ambient noise), and, from the intermediate work file, a sound speed profile. Wave height and wind speed values may be obtained from observations, weather forecasts, or climatological atlases. Bottom type may be taken from the ICAPS atlas file, as displayed by the PROFGEN program, or from the Naval Warfare Planning Charts for the ASW Prediction Area of interest. Default values are supplied by the program for volume and layer scattering coefficients. The supplement to this volume presents charts of scattering coefficients for the world's oceans. The values found there can be input by the user.

SHARPS output consists of tables of active and passive ranges, both ILR and BLR, for the sonars listed at specified speeds and modes of operation. Sample output displays are provided in the classified supplement to this volume. The modes vary depending on the sonar system and include omnidirectional transmission (ODT), processed directional transmission (PDT), rotational directional transmission (RDT), modest improvement program -- long range (MIP-LORA), test of reliability and maintainability --omnidirectional transmission (TRAM-ODT), and prairie masker (PM). Inner and outer ranges for the first convergence zone (CZ) annulus are given together with the depth, in fathoms, required for reliable convergence zone transmission. Bottom bounce forecasts contain a sonar depression angle followed by a forecast range at that depression angle. Forecasts are based on an assumed ship speed of 12 knots and target depth of 60 ft. The ranges displayed define a bottom

bounce annulus, being the minimum range for 50% POD, range of maximum signal excess, and maximum range for 50% POD.

Two counterdetection range values, or ranges at which a submarine may detect active sonar, are supplied. The first number, "TRACK," is the maximum counterdetection range for continuous tracking of the pinging sonar by a BQR-2B-equipped submarine at 300 ft. The second number, "MAX," is the maximum counterdetection range possible and includes convergence zone paths when they occur.

Target depth for convergence zone forecast is assumed to be 60 ft. The absence of a forecast convergence zone range or a zero minimum depth indicate, based on the water depth and sound speed profile, no convergence zone path is available.

Passive detection ranges at 6 knots against quiet and noisy threat submarines are supplied for sonars with passive capability. Both ILR and BLR are given for each case.

SHARPS recommends deployment depths for variable depth sonars which maximize detection ranges against a target at 60 ft. The passive performance forecasts for these sonars are computed for the recommended depth against a medium speed nuclear target at its best depth to avoid detection, sonic layer depth plus 200 feet.

12.0 ACTIVE ACOUSTICAL SENSOR RANGE PREDICTION (ACTIVE ASRAP) SYSTEM

Active ASRAP, or ACTIVE, computes maximum 50% probability of detection ranges for the SSQ-47 and SSQ-50 active sonobuoys, based on a single ping, using the empirical AMOS equations for two-way transmission loss. The model considers all frequency combinations available for these sonobuoys and the sensor/target depth combinations shallow/shallow, deep/shallow, shallow/deep, and deep/deep. Sonobuoy depth settings determine the shallow and deep sonar cases. Target depths are set at 60 ft for the shallow case and $30\sqrt{SLD}$ (with a minimum of 100 ft) for the deep case. ACTIVE range prediction products for the SSQ-47 and SSQ-50 are shown in the classified supplement. As an option, the operator may request display of one-way transmission loss data at 0.25 nmi intervals out to 12.0 nmi at the frequencies available for each sonobuoy. Continuations of these displays provide values for ranges 6.25 to 12.00 nmi. Sample displays are given in the classified supplement.

ACTIVE retrieves the sound speed profile from the intermediate file. Default values, for which the user may substitute his own data, are built in for target strength and recognition differential. The defaults used are displayed at the end of the program run. They are also given in the supplement to this volume. The user must input wave height, which is used to calculate ambient noise via modified Wenz Curves.

13.0 AUTOMATED DETECTION PREDICTION SYSTEM (ADEPS)

The ADEPS model computes performance prediction measures for any of a set of 12 sonobuoy patterns. In order to minimize load on the computer system and reduce response time, ADEPS uses a single-pass algorithm rather than an iterative procedure. This mathematical approach assumes that the detection probability calculated for a small subarea is representative of the entire area for which coverage is provided. Figures 13-1 and 13-2 illustrate the test subareas for the Area Search and Barrier Search cases, respectively. ADEPS has no provisions for considering multiple depth settings or for predicting coverage for other than the 12 rigidly defined patterns in its files.

The twelve patterns consist of sets of 8, 16, 24, or 32 buoys arranged in 2, 3, or 4 rows (figure 13-3). The operator chooses row spacing (Area Width) and lateral buoy spacing (Area Length) for each pattern. The relationships between area width and row spacing, and area length and lateral spacing, are given in figure 13-3. The three patterns of two rows can be used as barriers, either double or, by assigning zero Area Width, single line barriers.

The operator selects the appropriate propagation loss case from among those run in FACT and supplies the added data (sigma FOM, source level, ambient noise, and recognition differential) required to solve the passive sonar equation. LATRAN computes FOM and probability of detection and displays lateral range curves. Conceptually, the procedure followed by ADEPS uses the lateral range curves to generate probability surfaces concentric about each buoy and combines these surfaces into a probability field for the buoy pattern. Figure 13-4 illustrates the propagation loss and lateral range curves displayed by ADEPS in response to the user's selections. When the choices are satisfactory, the operator may proceed to run the Area Search or Barrier Search model subject to those conditions.

The Area Search Model computes and displays (figure 13-5) the average probability of detection, number of events, and cumulative probability over time, P(t). The target submarine is assumed to be within the area of coverage provided by the buoy field. The probability of detection, POD, is evaluated within a sample subarea (see figure 13-1) near the center of the pattern which represents the smallest segment containing a repeating probability distribution. The result is applied to the entire coverage area. Instantaneous POD's are assessed at the centers of 2-nmi squares in the test area and ranked. On the basis of the monitor cycle identified by the operator, ADEPS selects subsets of these ranked values to determine buoy pattern performance. Average POD is the simple average of the POD's in the ranked subset corresponding to the monitor cycle chosen. "Events" refer to crossings of ridges in the probability surface where POD = 0.5 by the target submarine while moving in the sample area. P(t) is the probability, accumulated over time, that an event occurs. The output display includes, in the upper right corner, a schematic of the buoy pattern selected.

The Barrier Model assumes that a target submarine tracks toward the buoy pattern in a corridor-like sample area extending 110 nmi perpendicularly from near the center of the barrier line closer to the target (see figure 13-2). The POD contours in the subarea are assumed to be typical of those at the same perpendicular distance from any point along the barrier front. The ADEPS output display for the Barrier Model, figure 13-6, provides plots of Barrier Line Efficiency versus Range

and Barrier Instantaneous POD versus Time. Line Efficiency is the percentage probability of detection versus range for the sonobuoy pattern. Another way to think of it is as a composite lateral range curve for the pattern. The start range, the distance from the barrier specified for the target at time zero, and the barrier location is clearly indicated on the graph. The speed of the target (Sub Speed), range (Sub Range), and the standard deviation of the range (Range Sigma) are supplied by the operator for calculating Instantaneous POD versus Time. That measure of effectiveness represents the product of the probability of detection at a given range with the probability that the target is located at that range at the time indicated. The "BARRIER" line on the graph indicates the time at which the target would cross the barrier front if it proceeded from the Sub Range at time zero maintaining a constant Sub Speed.

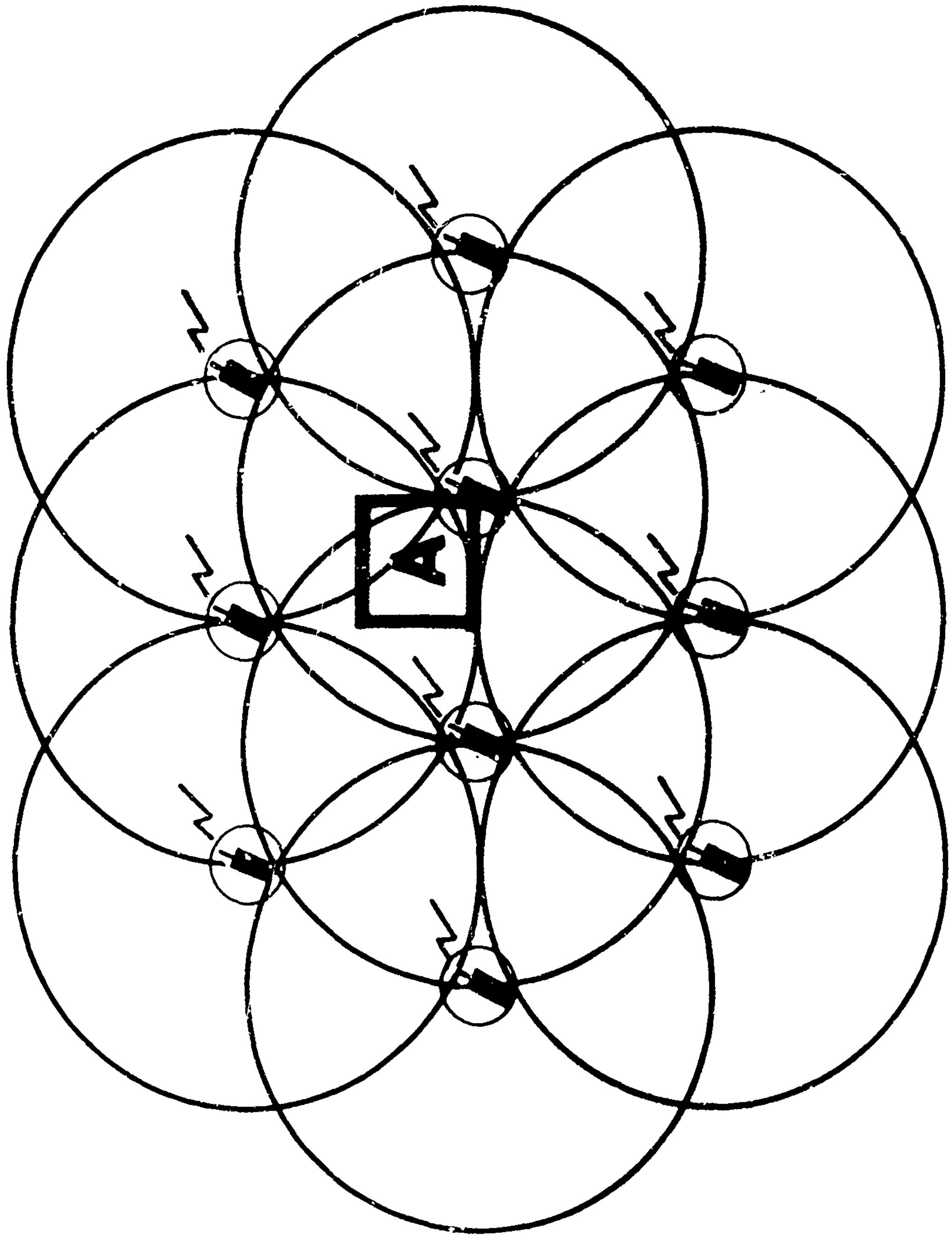


Figure 13-1. Area Search Subarea

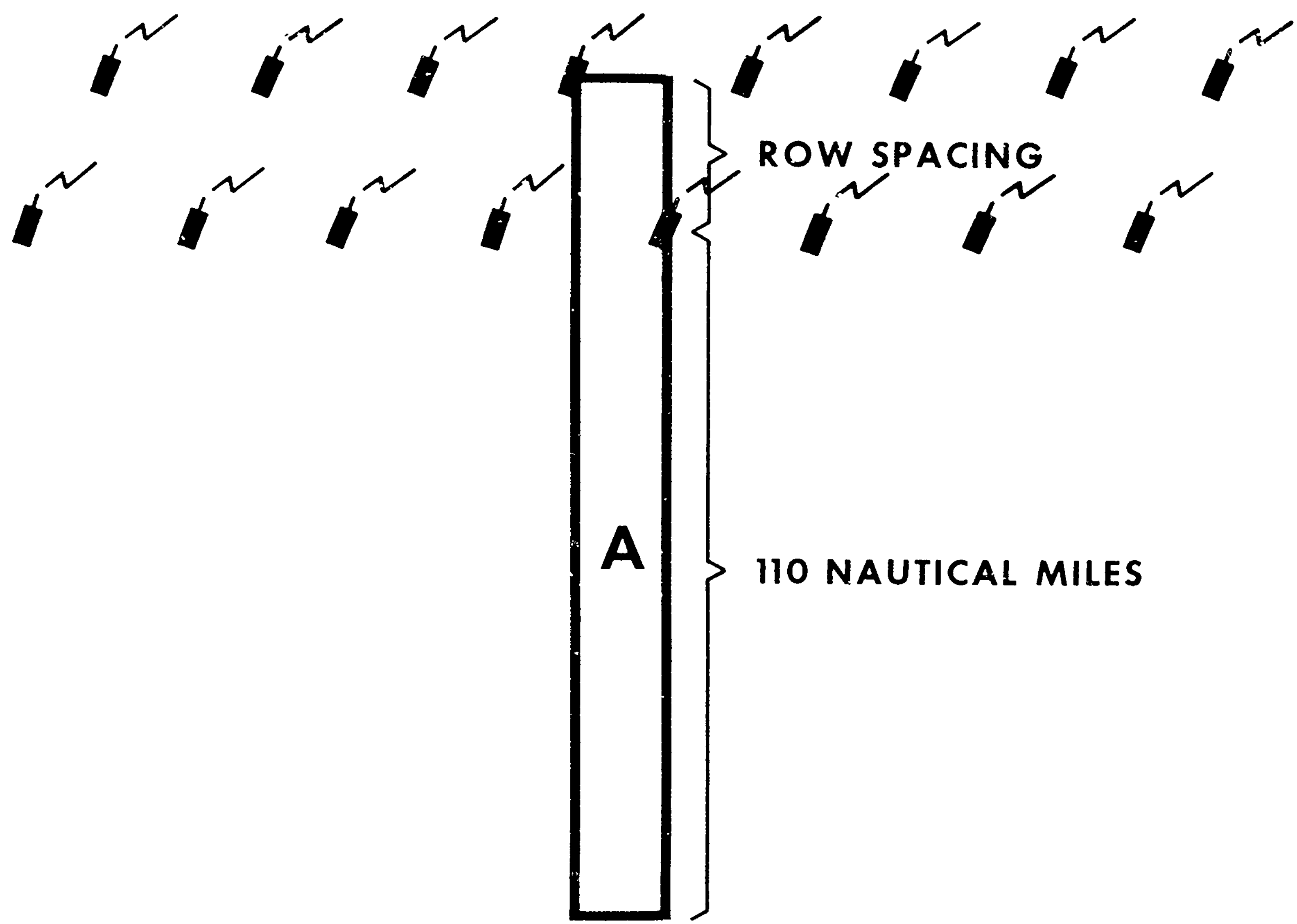
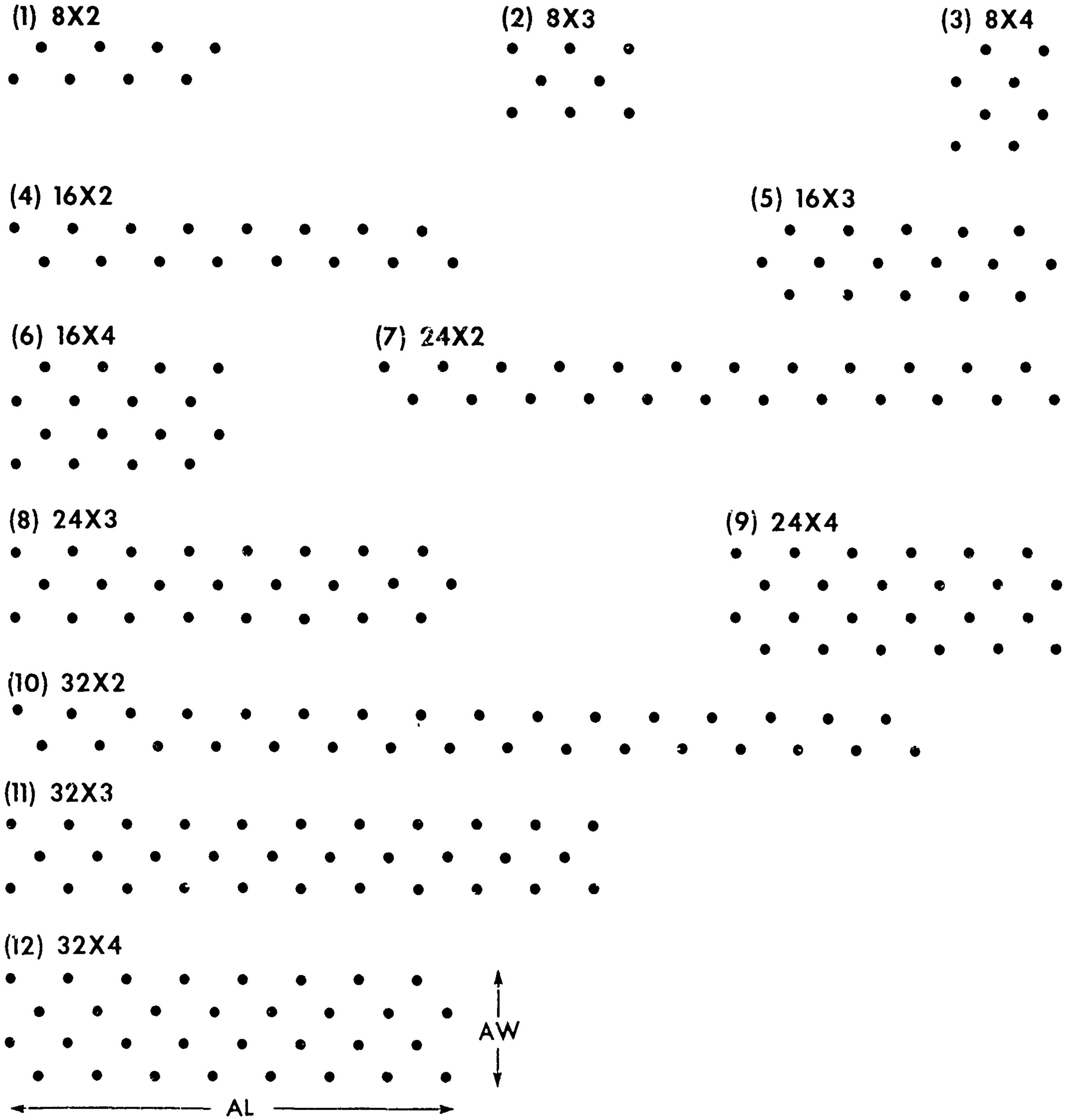


Figure 13-2. Barrier Search Subarea.



Area Width (AW):

Row Spacing x (# rows -1)

Area Length (AL):

Rows Equal-Lateral Spacing x (# buoys per row -.5)

Rows Unequal-Lateral Spacing x (# buoys in shorter row)

Figure 13-3. ADEPS Sonobuoy Patterns.

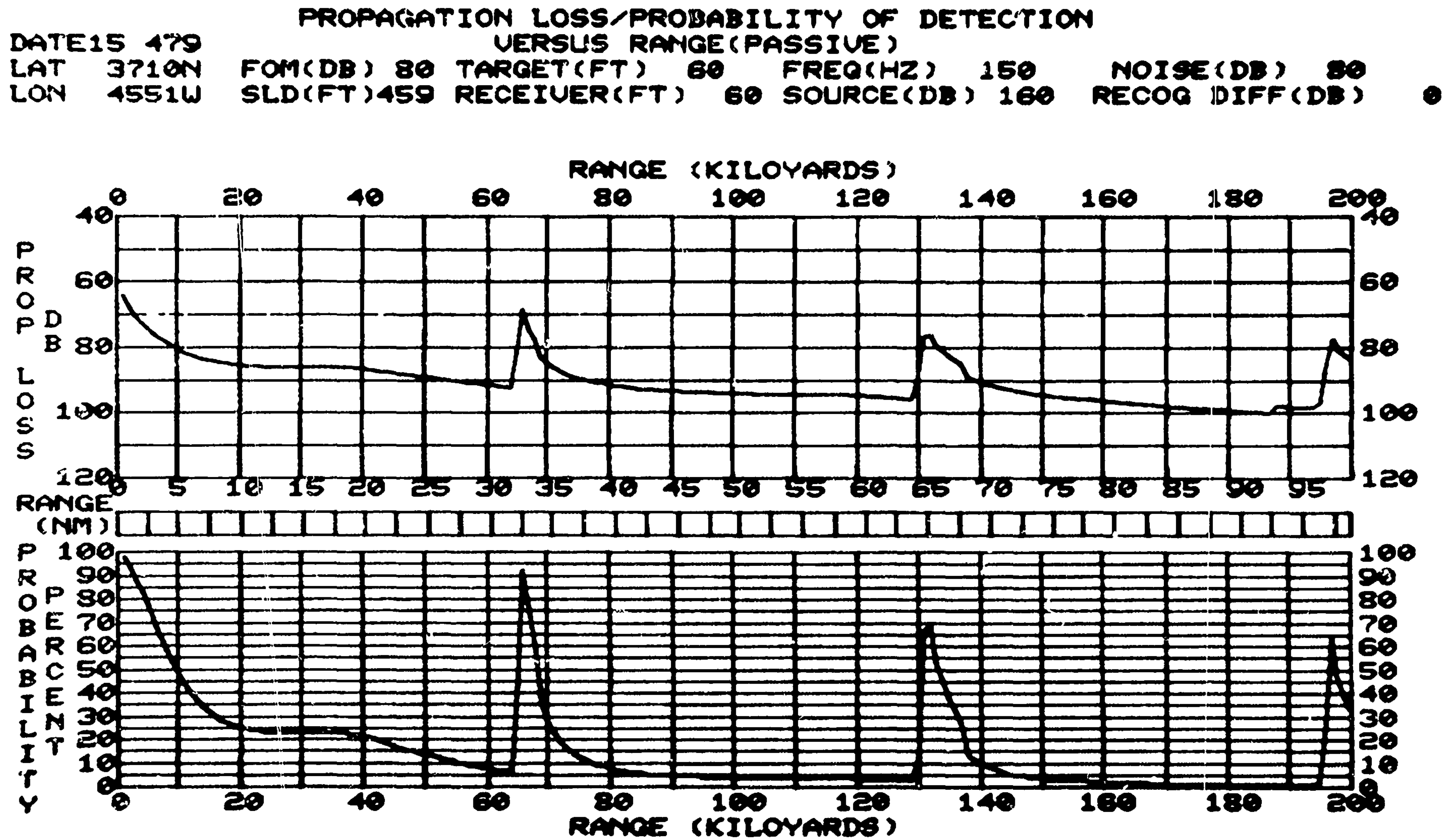
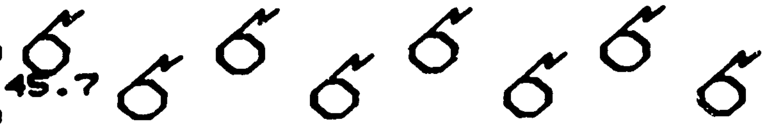


Figure 13-4. ADEPS Propagation Loss and Lateral Range Curves

BUOY GEOMETRY

```
**AREA SEARCH MODEL***
PATTERN NO.   1       ROW SPACING(NM) 80.0
NUMBER OF BUOYS  8    LATERAL SPACING(NM) 45.7
NUMBER OF ROWS  2     AREA LENGTH(NM)160.0
MONITOR CYCLE ALL     AREA WIDTH(NM) 80.0
- - - - - - - - - - - - - - - - - - - - - - - - -
SUBMARINE SPEED =  6.00
AVERAGE PROBABILITY OF DETECTION = 49.22
NUMBER OF EVENTS =202
AVERAGE DISTANCE TRAVELED BETWEEN EVENTS =  4.43
```



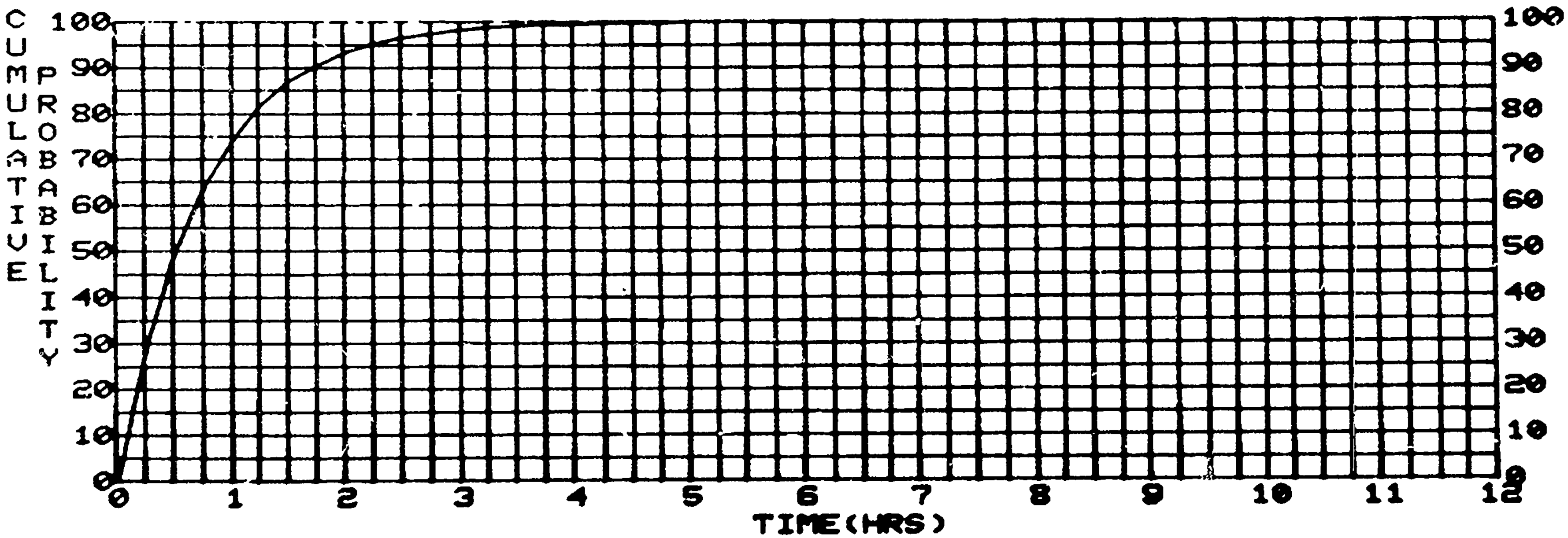


Figure 13-5. ADEPS Area Search Output

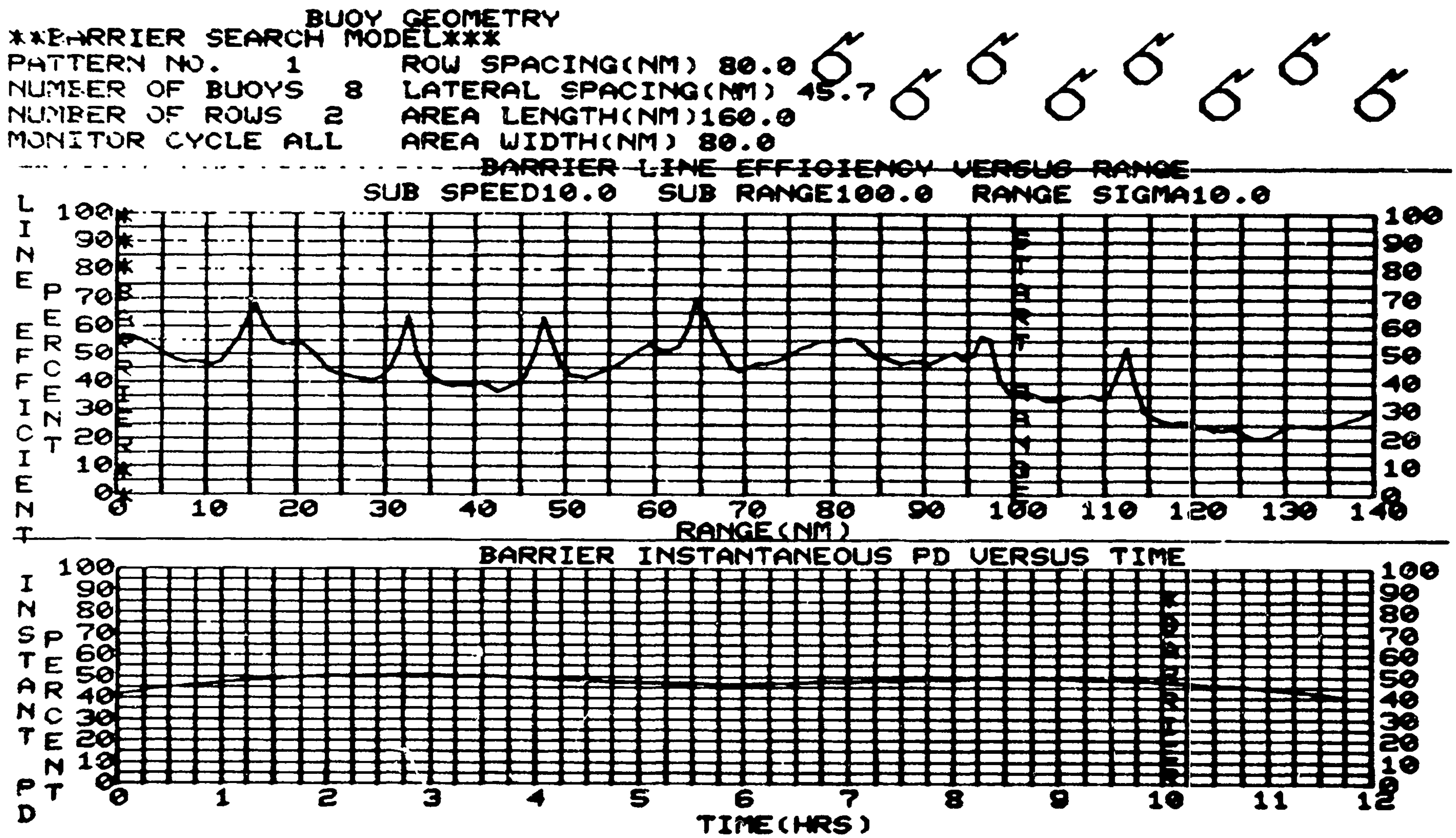


Figure 13-6. ADEPS Barrier Search Output

14.0 TACTICAL ASW SONAR DECISION AID (TASDA) PACKAGE

14.1 PROGRAM OBJECTIVES

TASDA operations may be divided into two distinct functional objectives: the creation of a sonobuoy tactics file tape library and the application of Monte Carlo game theory to produce optimum sonobuoy field deployment for ASW (Anti-Submarine Warfare). The sonobuoy tactics file is created by employing program GEOMT while TASDA addresses the target threat definition, simulation, and analysis.

14.2 GEOMT

14.2.1 Sonobuoy Position Planner Chart

The Sonobuoy Position Planner Chart (SPPC) shown in Figure 14-1 is always used to map the buoy pattern configuration. For most patterns it will be possible to indicate the relative buoy position coordinates exactly within a rectangular grid where x is an integer value between -16 and 16 inclusive and y is an integer value between -13 and 13 inclusive. Such patterns will be referred to as CLASS A patterns. A CLASS A pattern may be described merely by indicating the appropriate "buoy catalog numbers" found in the SPPC (1-891). (Note that the origin is represented by No. 446.) For example, a square pattern about the origin could be described in several ways such as (412, 414, 478, 480) or (378, 382, 510, 514), etc. However, since all such groups are equivalent, it is best for purposes of display to select the smallest square. A typical 5-6-5 buoy configuration might be selected as (376, 378, 380, 382, 384, 441, 443, 445, 447, 449, 451, 508, 510, 512, 514, 516); that is, BUOY 1 (No. 376), BUOY 2 (No. 378), etc. The user should first encircle all appropriate catalog numbers representing the pattern. Then he should assign buoy tag numbers to each location from 1 to NB (number of buoys). The maximum value for NB is 64. Recording the buoy catalog numbers from the SPPC as input must be performed in numerical tag number sequence. For example, the following pattern:

```
        1
  4           2
        3
```

could be defined as (413, 447, 479, 445) from Figure 14-1, but not as 413, 445, 447, 479) since this would destroy the intended sequence of buoy tag numbers. It is also imperative that the user exercise care in establishing buoy No. 1 and buoy No. 2 positions in the pattern since the distance between these buoys will serve as a "handle" on the pattern. That is, the optimum buoy spacing for every geometry analyzed by the TASDA program will be stated in terms of the spacing between BUOY 1 and BUOY 2, referred to as BUOY 1-2 SPACING. By selecting the BUOY-TO-BUOY DISTANCE CALCULATION option, the user may easily obtain various key distance measurements and associated x, y components relative to the BUOY 1-2 SPACING. This table of relative distance ratios could be referred to at a later date, knowing the BUOY 1-2 SPACING, to produce absolute distance measurements at a glance.

SONOBUOY POSITION PLANNER CHART

BUOY CATALOG NUMBER 446 REPRESENTS THE ORIGIN
INDICATE A BUOY LOCATION BY CIRCLING THE APPROPRIATE CATALOG NUMBER
NUMBER THE BUOYS (FROM 1-NB) AS DESIRED
RECORD THE BUOY CATALOG NUMBERS OF BUOYS 1-NB (IN SEQUENCE)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132
133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198
199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231
232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264
265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297
298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330
331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363
364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396
397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429
430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462
463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495
496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528
529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561
562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594
595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627
628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693
694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726
727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759
760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792
793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825
826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858
859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891

Figure 14-1. Sonobuoy Position Planner Chart

Some patterns may not be described exactly within the SPPC constraint that buoy position (x, y) be integer-valued within the specified limits. Such patterns will be referred to as CLASS B patterns. For example, consider a 7-buoy 120-degree wedge pattern. The schematic of this configuration may be approximated with the SPPC as (338, 356, 374, 386, 410, 416, 446). However, the actual wedge angle of the approximation is 122 degrees. If the user does not consider this approximation adequate, the capability exists to input the exact dimensionless buoy coordinates (integer range -1000 to 1000). Although the above approximation from the SPPC is required input, all computations and final output are based upon the user-input coordinates. The required input from the SPPC serves only for graphic display purposes of the general field pattern. If a user inputs the coordinates, he must also input a buoy pattern schematic anomaly message; i.e., a descriptive title of the pattern.

14.2.2 Dimensionless Buoy-To-Buoy Distance Calculations

Buoy-to-buoy distance calculations are provided to enable the user to compare selected inter-buoy pattern distances to the reference distance between buoy 1 and buoy 2, both in magnitude and x, y components. Since optimal sonobuoy deployment is stated in terms of the actual (absolute) value of BUOY 1-2 SPACING (in nautical miles), the buoy-to-buoy distance calculations tabular output is utilized to provide quick conversion from relative distance value to absolute distance value.

Example

Consider the following symmetric seven-buoy pattern:

1		2
3	4	5
6		7

The user may request a single buoy-to-buoy distance calculation to facilitate the conversion effort at a later time by specifying buoy 1 and buoy 4. The resulting table would have one line as follows:

Buoy to Buoy		D Ratio	X Ratio	Y Ratio
1	4	0.559	0.500	0.250

Suppose the analysis for this pattern from TASDA B yields an optimal BUOY 1-2 SPACING of 20.0 miles. Using the buoy-to-buoy distance calculation table, one can make the following mental observations:

distance between buoy 1 and buoy 4 = optimal buoy spacing X D Ratio (1-4)

= 20.0 X 0.559

= 11.18 nmi

distance between buoy 3 and buoy 4	=	optimal buoy spacing	X X Ratio (1-4)
	=	20.0	X 0.500
	=	<u>10.0 nmi</u>	
distance between buoy 1 and buoy 3	=	optimal buoy spacing	X Y Ratio (1-4)
	=	20.0	X 0.250
	=	<u>5.0 nmi</u>	

All other inter-buoy distances are multiples of the above values. When the sonobuoy geometry is complex, perhaps asymmetric, this optional feature becomes more valuable.

14.3 TASDA

The TASDA program is a Monte Carlo model used to predict and compare passive sonobuoy field detection capabilities. The model establishes buoy configuration patterns and simulates the passage of a target through or about the field. The TASDA program estimates seven measures of effectiveness; probability of detection by one or more buoys, by two or more buoys, and by three or more buoys; mean holding time by one or more buoys, by two or more buoys, and by three or more buoys; and mean time to first detection.

Two target types are simulated, nuclear and conventional. The nuclear target remains permanently submerged; only its velocity is input. The conventional target alternately submerges and snorkels; its velocities during submerged and snorkeling operations are inputs. The lengths of time submerged and snorkeling are assumed to be uniformly distributed between input limits.

ASW aircraft often prosecute AOU's (areas of uncertainty) given as bearing boxes, ellipses, or circles. Bearing boxes are defined by a bearing half width, and a maximum length for the line of bearing. Ellipses are defined by a center, semi-major and semi-minor axes, and orientation; circles by a center and radius length.

AOU's can be simulated in TASDA by utilizing the proper initial area of uncertainty option. Two options for target motion are provided: transiting and holding. The transiting target's movement is described by specifying starting and finishing blocks (bearing boxes). Note that the start and finish blocks may be compressed into start and finish lines or may overlap. A point is chosen randomly (uniformly) from within the start area and from the finish area; in this way a target track is established (see figure 14-2).

In the holding case, the target's initial position is a random variable which the user may specify to be either uniform or normal. In the uniform case, the target's starting position is randomly selected from a uniform probability distribution over a rectangular area. This area of uncertainty (bearing box) is defined by specifying the coordinates of the upper left and lower right vertices of the rectangle. In the normally distributed case (ellipse or circle), the starting position of the target is selected from a bivariate normal (hill-shaped) distribution with 0 or 90 degree angle of orientation relative to the X-axis, which is defined by specifying

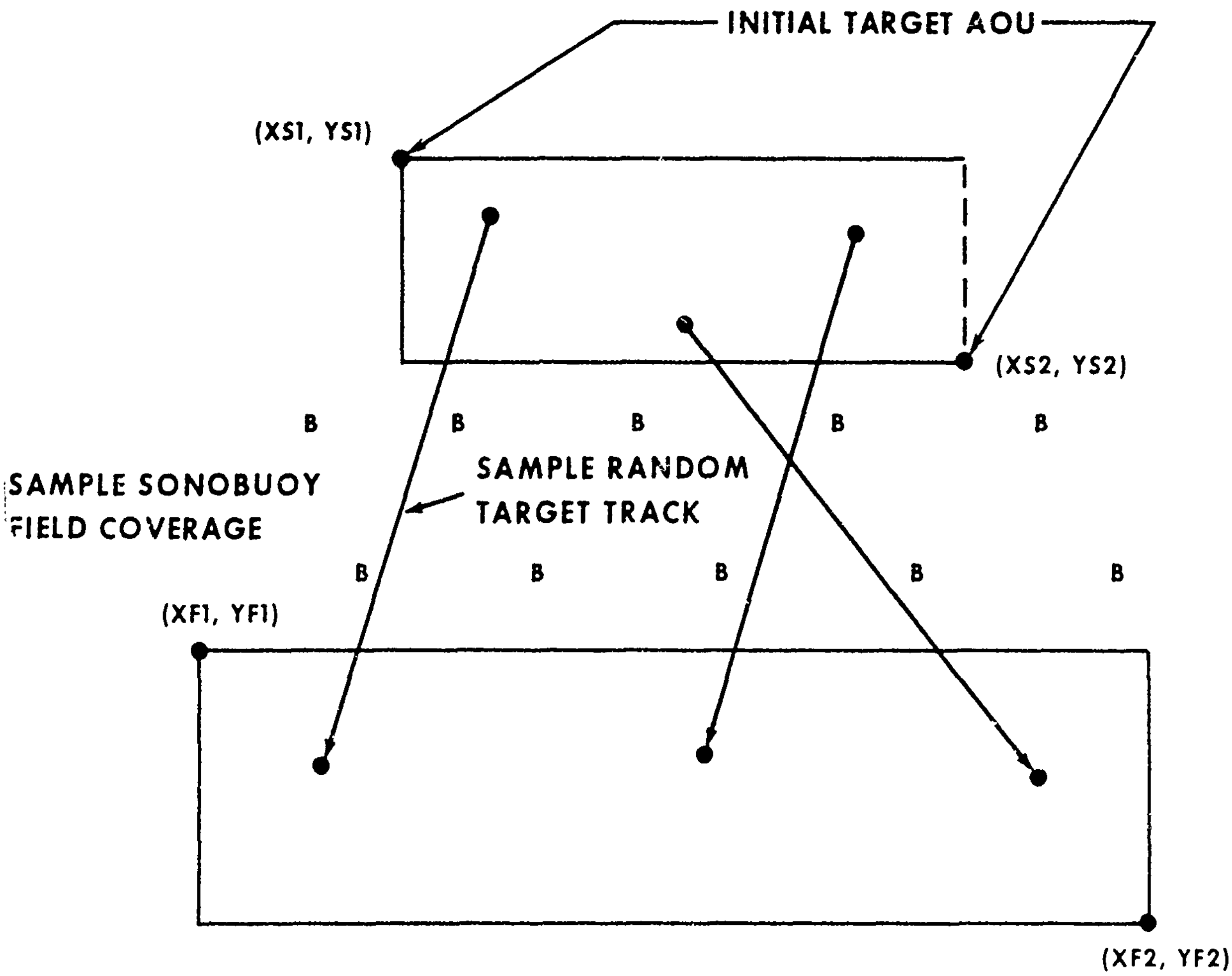


Figure 14-2. Uniformly Distributed Transiting Target Area

the center of the distribution and the standard deviations (sigma) in both the X and Y directions (see figure 14-3). For an elliptical AOU, sigmas for X and Y are equal to half the lengths of the semi-major and semi-minor axes, respectively. Sigmas for X and Y in the circular AOU are equal to half the length of the radius each.

The following are guidelines for relating initial contact information to the target distribution for a holding target case.

AOU Type Contact	Holding Target Distribution
Bearing	Uniform
Circle	Bivariate Normal
Ellipse	Bivariate Normal

When the target's starting position distribution has been established, the movement of the target's location is defined by vectors with bearings selected from a uniform distribution between the input values DIRMAX and DIRMIN, and lengths specified by the input value DISMAX (see figure 14-4). Bearing limits for a holding scenario are defined relative to the model's "north," which is the positive Y direction for a given search area. The bearings are measured in degrees clockwise from the minimum to the maximum bearing limit. DISMAX is the speed of advance of the target multiplied by the time-on-station of the aircraft.

The aircraft is simulated with very little detail. The flight path is described only to the extent of specifying the elapsed time before arrival on station. The expression "time on station" used in the model refers to the time the aircraft will remain on station after the entire sonobuoy field is in place; i.e., there is no time allotted to buoy deployment. Once the aircraft arrives on station, all buoys come up and remain up for the entire target track.

The time late is input independent of aircraft-on-station time. Time late is the time ellapsed between the information establishing the search area (AOU) and the time the buoy field is in place. For a holding scenario, a bearing and starting point within the holding area are randomly chosen and the target travels a distance equal to the speed of advance of the target times the time late of the aircraft from the original point chosen by the computer. The maximum time late is 8 hours. The effect of time late is to internally expand the area of search.

The RF range is the maximum allowable distance between the aircraft and a sonobuoy which permits radio reception, with the position of the aircraft fixed at coordinate point (0,0) for the simulation. Buoys outside RF range of (0,0) do not contribute to the measure of effectiveness.

The simulation proceeds as follows. The game time (the length of time the aircraft is monitoring each target track) is divided into the time steps. At each time step, $\cong$ 10 mins., the target position is updated and each buoy is checked for target contact. A contact is recorded on BUOY J if the signal excess on BUOY J exceeds 0. Signal excess is defined in the following equation:

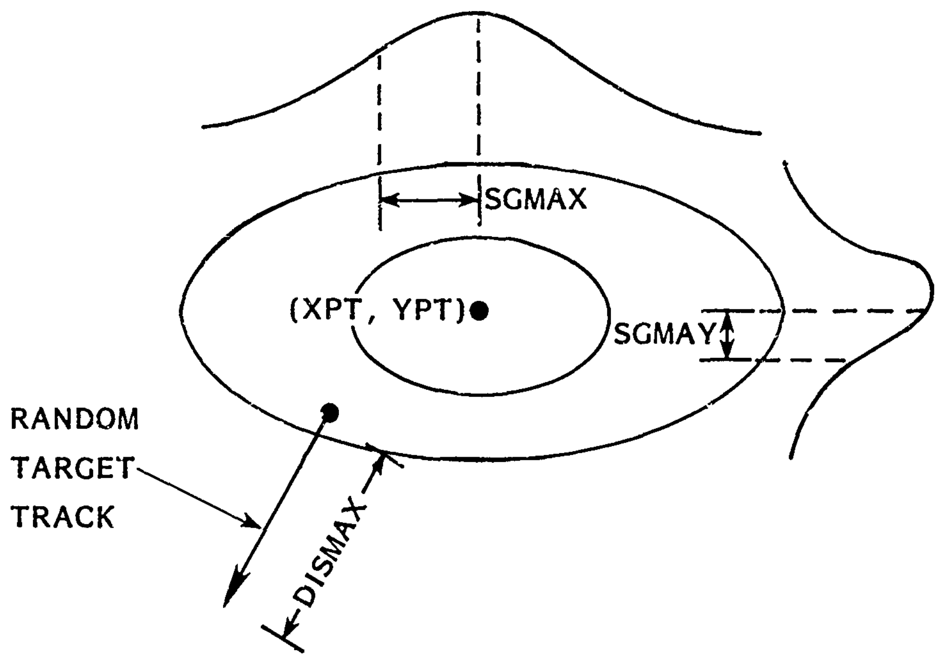


Figure 14-3. Normally Distributed Initial Target Area

NOTE: XS1, XS2, YS1, YS2, SF1, SF2, YF1, YF2 Are All Overridden for This Case.

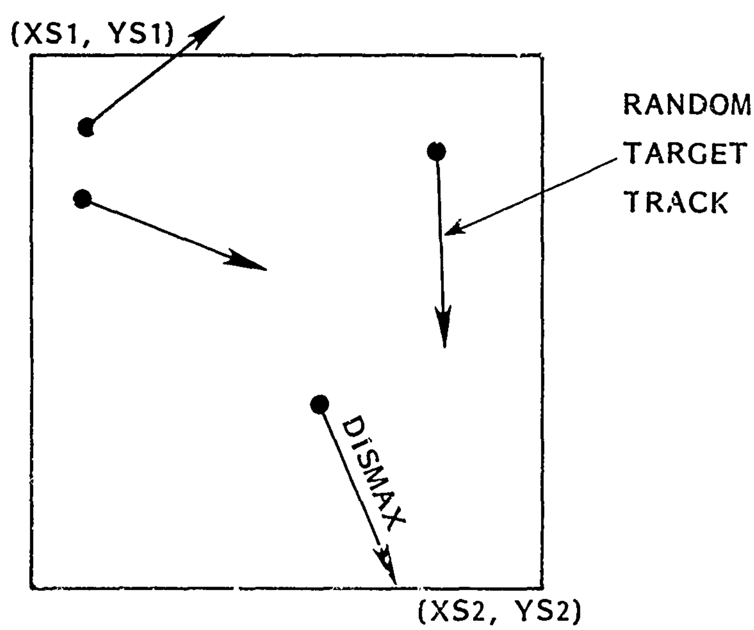


Figure 14-4. Uniformly Distributed Holding Target Area

NOTE: XF1, XF2, YF1 and YF2 Have No Meaning for This Case.

$$SE(J) = FOM - PL(J) + BBF(J) - PLVAR$$

where SE(J) = Signal excess for Jth Buoy (db)

FOM = Figure of Merit (db)

PL(J) = Propagation Loss (db) for Jth buoy, calculated as a function of buoy-to-target distance from an input propagation loss curve.

BBF(J) = Normally distributed buoy-to-buoy fluctuation employed once per target track for the Jth buoy.

PLVAR = Propagation loss fluctuation from a Rician Distribution employed once per time step. This fluctuation is suppressed in the convergence zones.

If two consecutive contacts occur on the same buoy, a detection is recorded. The relative frequency of detected tracks to total tracks is used as an estimate of probability of detection. The total time a target is held by one or more buoys divided by the total number of unbroken detection intervals is used as an estimate for the mean holding time by one or more buoys. Analogous procedures are used to estimate mean holding time by two or more and three or more buoys. Once the first detection is made for a target track, its time is recorded, and the total of these times, divided by the number of detected tracks, is used as an estimate of mean time to first detection.

14.3.1 Preliminary Calculations

Average Submarine Speed

Nuclear Submarine: VELAVG = VEL

where VEL is input as submerged speed

Conventional Submarine: VELAVG = (a VEL + b VELSNK)/(a+b)

where VELSNK is input as snorkeling speed

a = average submerged time

b = average total time

Distance Traveled During Aircraft Time Late

$$DF = TMELTE \times VELAVG/60.$$

where TMELTE = aircraft time late in minutes

VELAVG = average submarine speed (knots)

Average On-Station Distance Traveled By Transiting Submarine

$$\text{DISMAX} = \frac{\sum_{i=1}^{4} \sum_{i=1}^{4} \overline{A_i\ B_j}}{16.0} - \text{DF}$$

Where A_i and B_j are the mid-points of the rectangles formed by perpendicular bisectors of the starting and finishing block (figure 14-5).

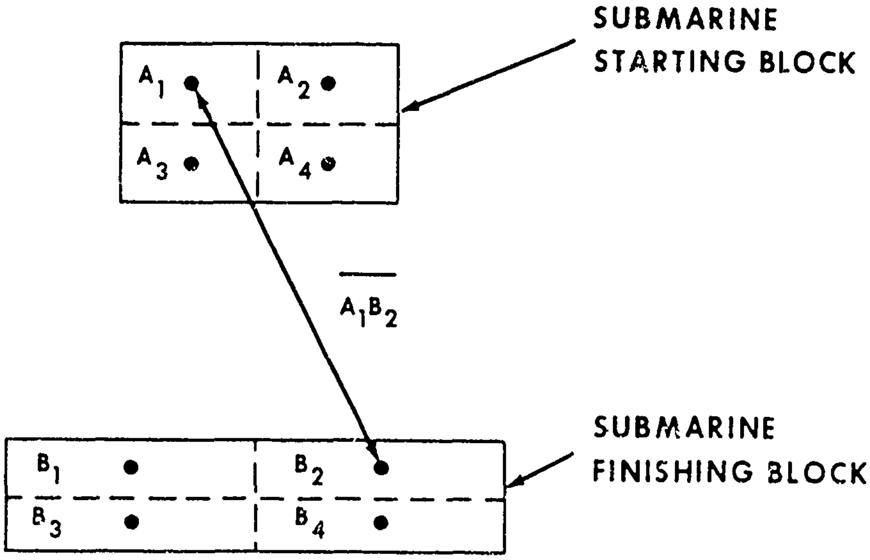


Figure 14-5. Distance Traveled by Transiting Submarine

Average Game Time

RUNT = DISMAX/VELAVG

where DISMAX = average on-station submarine travel

VELAVG = average submarine speed

Submarine Statistics Printout

The following submarine quantities are printed out, provided that the appropriate inputs were acceptable:

- Average Distance Traveled During Time Late
- Average Distance Traveled During On-Station
- Average On-Station Run Time
- Average Speed

14.3.2 Minimum And Maximum Buoy Spacing Limits

Each geometry is assigned default values for minimum and maximum buoy spacing limits of 10.0 and 40.0 nautical miles, respectively, during compilation. The user may override these values with his own selections for each geometry in GEOMT. The buoy spacing limits are used by the TASDA program to govern the actual BUOY 1-2 SPACING settings throughout the simulation. It is possible to redefine the buoy spacing limits, however, via TASDA inputs. TASDA inputs enable the user to reset the minimum (maximum) buoy spacing limit(s) uniformly for all geometries.

The buoy spacing test points are determined by the TASDA input variables IGRAN, SPHI, and SPLO. If IGRAN = zero, there will be seven such test points (uniformly incremented). The maximum value of IGRAN is 10.0. The low and high buoy spacing values appear on the geometry tactics file output for each geometry. If SPLO (SPHI) is left blank, each geometry will retain its individual low (high) buoy spacing limit(s). Otherwise, all geometries will take on the same SPLO (SPHI) buoy spacing limit(s). Any of these three variables may be activated independently of the others.

Example: IGRAN = 5.0

SPHI = 30.0

Suppose the geometry tactics file contains two geometries with the following buoy spacing limits:

Geometry No.	Low Buoy Spacing	High Buoy Spacing
1	10.0 (nominal)	40.0 (nominal)
2	2.0	28.0

The resulting buoy spacing test points for the two geometries becomes:

Geometry 1: 10.0, 15.0, 20.0, 25.0, 30.0 miles

Geometry 2: 2.0, 9.0, 16.0, 23.0, 30.0 miles

14.3.3 Minimum And Maximum Geometry Radii

The geometry radius is defined to be the distance from the origin to the most remote sonobuoy. The dimensionless geometry radius is calculated from the relative buoy coordinates and converted to minimum and maximum absolute values from minimum and maximum buoy spacing limits. Should the aircraft RF range (defined in TASDA A) be exceeded by a geometry radius, one or more sonobuoy signals would be voided. The TASDA B operation will terminate its simulation search when this situation occurs, utilizing the information obtained to this point, and an appropriate message will appear in the output for the geometry under consideration. TASDA B operation then proceeds to succeeding geometries.

14.3.4 Multiple Depth Sonobuoy Capability

TASDA can be used to simulate sonobuoy fields with buoys located at more than one depth. Up to three depths are permissible. In order to process multiple depth sonobuoy fields, the user must input the propagation loss for each depth, as well as the depth assignments of each sonobuoy in the field. Each sonobuoy then remains fixed at the selected depth for the entire simulation, although the X, Y position can change based on buoy spacings. The following example will serve to illustrate the multiple depth capability of the model.

Example

A field of 11 sonobuoys is dropped with the following geometrical configuration:

```
1   2   3   4
  5   6   7
8   9   10  11
```

Buoys 2, 4, 6, 9, and 11 are placed at depth 1 to 90 feet. Buoys 1, 3, 5, 7, 8, and 10 are dropped at depth 2 to 1,000 feet. Two propagation loss curves must be input to the model representing the particular environment at depths of 90 and 1,000 feet. Input to the program would be:

Buoy #	1	2	3	4	5	6	7	8	9	10	11
Schedule # 1	2	1	2	1	2	1	2	2	1	2	1

The TASDA B program provides a special multiple depth sonobuoy default feature which should be taken into account when preparing the TASDA A multiple depth sonobuoy schedule inputs. The user may elect to assign buoy depth schedules to as many as six specific geometries. However, it is anticiapted that this liberal allocation will rarely be utilized. Therefore, the sonobuoy depth schedule for the sixth geometry selection is preset for PL data set 1 only, and for 64 buoys. In the event that the TASDA B multiple depth analysis involves a geometry without an associated sonobuoy depth schedule, the program will automatically assign a single schedule from the sixth geometry schedule assignment to this geometry and an appropriate message will accompany the printed output. Thus, the user may assign multiple depth sonobuoy schedules for specific geometries and still obtain analysis of any geometry in the geometry tactics file at the default PL data depth set 1 (the total number of geometries cannot exceed six for a given run).

14.3.5 Propagation Loss Data

Propagation loss (PL) data are supplied to the TASDA program via FACT output or direct keyboard input. A single PL data set may contain propagation loss values (db) from 10 to 200 nautical miles or kiloyards in range. If more than one set of PL data is employed for a given run, they must all be in terms of the same units (kiloyards or miles). Also, all PL data sets must have the same range limitation for a given run.

14.3.6 Display Of User-Selected Inputs

A display showing all user-selected inputs is printed out with each TASDA A run. For the user's convenience, this display also indicates input format requirements and individual parameter limits.

14.3.7 Geometry Selection

If the user does not indicate the specific geometries to be processed by the TASDA B program, the program evaluates all geometries (up to six) which satisfy the minimum and maximum buoy constraints. It is assumed that a sufficient number of channels are available for continuous monitoring of all buoys.

14.3.8 Statistical Parameters

Random Number Seed

Random target tracks are generated using the program's random number generator. This algorithm requires a random number seed for initialization of the sequence of random numbers. The random number seed default value, 87654321, is sufficient to initialize this sequence. Two computer runs with identical scenario and tactical inputs will, in general, compare exactly only if the random number seed used in each run is the same. If for the same scenario, a different random number seed is used, the two outputs will differ only slightly within statistical error.

Buoy-to-Buoy FOM Fluctuation Input Guidelines

The use of TASDA as a pre-flight decision aid requires that the figure-of-merit value be estimated before measurements are taken. Figure-of-merit fluctuation is simulated by inputting a standard deviation of FOM for each buoy. Buoy-to-buoy FOM fluctuations simulate ambient noise fluctuations in the specific oceanographic environment. A random number is selected from a truncated standard normal distribution for each buoy and multiplied by the input standard deviation for the buoy, SIGB, to produce an FOM deviation for each buoy. The fluctuation on the FOM is assumed to be normally distributed with an associated one-sigma value in decibels.

The following one-sigma values for various oceanographic environments should provide useful guidelines for this input variable:

Oceanographic Area	One-Sigma Value (dB)
Atlantic	1.0 dB
Pacific	0.5 dB
Mediterranean	2.0 dB

by TASDA for determining detection by a buoy depends on the depth of that buoy; thus, up to three prop loss curves can be required. To satisfy TASDA, program FACT has been modified with the option to output prop loss curves for (up to) three source/receiver-depth combinations, and (up to) four frequencies within each combination.

Run time for TASDA on the NOVA varies greatly, depending on amount of output requested. A simple case (e.g., one tactic with six buoys, one prop loss curve, one figure of merit, quick run flag set) will run in under 5 minutes per buoy spacing. Increases in the numbers of tactics, spacings, prop loss curves, and figures of merit can readily increase run time to well over an hour.

14.4.1 Data Input on The NOVA

Both TASDA and GEOMT are convenient to run in batch mode where the input data are contained in a card deck. Usually, not more than a few of the ASW scenario parameters need to be changed from run to run, so most of the data deck remains intact. In conversational mode on the NOVA, however, it is impractical to force the operator to enter all needed parameters for every run; therefore, the "data card deck" approach has been adapted to NOVA operations. When the user runs either TASDA or GEOMT, the program first executes a data input module before executing the main body of the program. The data input modules allow the user to process the contents of a data input file (GEOMTIP:IM for GEOMT, TASDAIP:IM for TASDA) which resides permanently on disk. The data input file is analogous to a data card deck. The operator can select areas of the file to process, similar to examining and/or changing one card in a deck, before passing control to the main body of the program. (There is not necessarily a one-to-one correspondence between an "area" of the file and the contents of a data card as read by TASDA or GEOMT in batch mode.) Opportunity is given to process as many areas of the file as needed, as many times as needed, until the operator is satisfied with the contents of the file. It is important to understand that the data input file is read into computer memory not more than one time during an execution of the TASDA or GEOMT input module. All modifications, deletions, and additions that the user may make are performed in memory. The disk-resident file (which is read by the main body of the program) is not affected until the user explicitly instructs that updates made in core be written onto disk. Thus, if the user accidently deletes data or makes unwanted updates, he can terminate the run and start again with the original data input file.

Once a parameter or set of parameters is incorporated into the disk-resident data input file, it will remain there until it is changed, deleted, or the file is reinitialized. Thus, parameters that remain the same from run to run do not have to be entered for each execution.

The number of parameters needed for an execution depends on the ASW scenario defined by the user. For example, if the sub is defined as transiting, both a starting and finishing rectangle must be present (i.e., must be entered if it does not already exist) in the data input file, but if the sub is defined as holding, only the starting rectangle is needed. Similarly, if a multiple depth sonobuoy pattern is used, the depth schedule for the pattern must be present, but for a single depth pattern, no depth schedule is used. In all cases, data that exist in the data input file, but which are not needed for the current run, will not affect the program. Thus, unneeded parameters do not have to be deleted.

The data input modules execute in one of three modes, as requested by the user from the Option List. These are "Create Mode', "Examine Mode," and "Modify

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The data input modules execute in one of three modes, as requested by the user from the Option List. These are "Create Mode', "Examine Mode," and "Modify

Mode." For all of these, the module will "walk" the user through the necessary steps to input data. All displays of, and requests for, parameters are made in descriptive terms which should be self explanatory to the user with a working knowledge of TASDA and GEOMT data input requirements. The routing taken through the module is controlled by user response to options. It is important to carefully read the CRT screen to understand what the program is requesting.

In Create Mode, the user is defining his data input file for the first time. The program simply requests parameters in a logical order with few user options. Only parameters that are pertinent to the input data set being defined will be requested. For example, if the sub is defined as nuclear, no snorkeling speed will be requested.

In Examine Mode, the program will display the contents of an existing data input file. Each parameter is identified with a descriptive label. The user can select certain areas of the file to be displayed, or he can ask to see the entire file. Within the requested area, all parameters will be processed, whether they are prestored or not. For parameters that do not exist in the data input file, "no value" (or a similar indicator) will follow the label. Examine Mode provides a method for quickly reviewing the file contents to decide if modifications are needed before running GEOMT or TASDA.

Modify Mode requires the most input and decision making by the user. He can select areas of the file to be shown, or the entire file. The program outputs the value of a parameter stored in the data input file along with a descriptive label and asks the user if he wants to change it. If a parameter does not exist, "no value" (or a similar indicator) is shown. If the user indicates he wants to make a change, or if the parameter is not stored, the program repeats the descriptive label, prompting the user to enter a value. After the value is entered, or if the user has indicated no change, the program proceeds to the next parameter or next area. As in Create Mode, only pertinent parameters will be processed.

When processing is finished in any of the above modes, control is returned to the Option List. The user can select any mode, any number of times, to check his input and to correct errors.

The data input modules incorporate several features designed to help the user avoid making obvious errors. For example, if while running TASDA in Create or Modify Mode the user requests the source of prop loss data to be FACT output (Z999ICAP:IM) and further specifies the range units to be nautical miles, the program will output the following message:

```
WARNING: YOU HAVE REQUESTED PROP LOSS FROM FACT
         BUT SPECIFIED UNITS OF NAUTICAL MILES
         FACT PROP LOSS IS ALWAYS IN KILOYARDS
         UNITS OF PROP LOSS RANGE WILL BE CHANGED
         TO KILOYARDS.
```

The program will automatically change range units to kiloyards.

If Z999ICAP:IM is to supply prop loss data, the user must know how many source/receiver depth combinations it contains, the frequencies, and the number of range points. If he requests more depth combinations or more range points than are contained, or a non-existent frequency, the program will display an appropriate warning message, list the acceptable inputs, and ask the user to re-enter the parameter.

Whenever the user selects Create Mode (Option 4) from the Option List, he is asking that the current Data Input File be erased. It could be highly unfortunate if the user unintentionally keyed in Option 4. Therefore, a safeguard against accidentally destroying a Data Input File is needed. If a valid file exists, the program will output the following message:

```
A VALID TASDA DATA INPUT FILE EXISTS
PLEASE CONFIRM THAT YOU WANT TO RE-
INITIALIZE THE FILE
ENTER 0 TO CANCEL RE-INITIALIZATION
OR 1 TO CONFIRM RE-INITIALIZATION
(ENTER 0, OR 1):
```

Entering a "1" causes the program to proceed with Create Mode; a "0" causes the program to return to the Option List without re-initializing the file.

14.4.2 GEOMT: Typical Operating Sequence

The command "R GEOMT" causes the Option List to appear on the screen. A typical sequence of option selections follows:

Option 3: Examine contents of existing file.
Option 2: Make updates to file.
Option 3: Review updated file. Make hard copies for records.
Option 5: Write updated file onto disk.
Option 1: Execute main segment of GEOMT.

Another example:

Option 4: Initialize (erase) data input file. Program will request data to define at least one tactic. (This option should only be used when initializing a new disk. Afterwards, any changes, additions or deletions can be made with Options 2, 3, and 5.)
Option 3: Review what was input.
Option 2: Correct errors, if any.
Option 5: Write file onto disk.
Option 1: Execute main segment of GEOMT.

14.4.3 TASDA: Typical Operating Sequence

The command "R TASDA" causes the Option List to appear on the screen. A typical sequence of option selections follows:

Option 3: Examine contents of existing file.
Option 2: Make updates to file.
Option 3: Review updated file. Make hard copies for records.
Option 5: Write updated file onto disk.
Option 1: Execute main segment of TASDA.

Another example:

Option 4: Initialize (erase) data input file. Program will request data to define a complete ASW scenario. (This option should only be used the first time a disk is initialized. Subsequent changes can be made with Options 2, 3, and 5.)
Option 3: Review what was input.

Option 2: Correct errors, if any.
Option 5: Write file onto disk.
Option 1: Execute main segment of TASDA.

14.5 INPUT PARAMETERS

14.5.1 GEOMT Input Parameters

The GEOMT data input file (GEOMTIP:IM) is segmented into individual tactics. A maximum of 20 tactics may exist in the file at one time. The following is a list of parameters that may be required by GEOMT Data Input Module to define a single tactic:

TACTIC IDENTIFICATION LABEL
TARGET APPLICATION SELECTION
- conventional holding target
- conventional transiting target
- nuclear holding target
- nuclear transiting target

BUOY COORDINATES DEFINITION LOG
NUMBER OF BUOYS
NUMBER OF BUOY-TO-BUOY DISTANCE CALCULATIONS
BUOY SPACING LIMITS
- minimum spacing
- maximum spacing

BUOY POSITION ASSIGNMENTS
SPECIFIC BUOY COORDINATES (if COORDINATES DEFINITION FLAG = 1)
BUOY PATTERN SCHEMATIC ANOMALY EXPLANATION (if COORDINATES DEFINITION FLAG = 1)
BUOY-TO-BUOY DISTANCE CALCULATION REQUESTS (if NUMBER OF DISTANCE CALCULATIONS GT 0)

14.5.2 TASDA Input Parameters

The TASDA data input file (TASDAIP:IM) is segmented into nine categories according to type of data. The following is a list of parameters within each category that may be required to define an ASW scenario:

CATEGORY 1: TARGET CHARACTERISTICS
- TARGET TYPE
- TARGET MOVEMENT
- DISTANCE TRAVELED BY TARGET (if TARGET MOVEMENT = HOLDING)
- BEARING LIMIT 1 (if TARGET MOVEMENT = HOLDING)
- BEARING LIMIT 2 (if TARGET MOVEMENT = HOLDING)
- TARGET VELOCITY SUBMERGED
- TARGET VELOCITY SNORKELING (if TARGET TYPE = CONVENTIONAL)
- MIN SNORKEL TIME (if TARGET TYPE = CONVENTIONAL)
- MAX SNORKEL TIME (if TARGET TYPE = CONVENTIONAL)
- MIN SUBMERGED TIME (if TARGET TYPE = CONVENTIONAL)
- MAX SUBMERGED TIME (if TARGET TYPE = CONVENTIONAL)

CATEGORY 2: TARGET OPERATING AREA
- STARTING RECTANGLE COORDINATES
  - left X coordinate
  - right X coordinate
  - top Y coordinate
  - bottom Y coordinate

ENDING RECTANGLE COORDINATES (if TARGET MOVEMENT = TRANSITING)
left X coordinate
right X coordinate
top Y coordinate
bottom Y coordinate

CATEGORY 3: AIRCRAFT CHARACTERISTICS
TIME LATE
RF RANGE

CATEGORY 4: FIGURE OF MERIT
NUMBER OF FIGURES OF MERIT
FIGURES OF MERIT

CATEGORY 5: PROPAGATION LOSS
NUMBER OF PROP LOSS CURVES
SOURCE OF PROP LOSS CURVE(S)
(last parameter repeated by NUMBER OF PROP LOSS CURVES)
FREQUENCY OF PROP LOSS (if SOURCE OF PROP LOSS = FACT O/P)
UNITS OF PROP LOSS
NUMBER OF RANGE PTS ON PROP LOSS CURVE (MAX = 200.)
PROP LOSS CURVE LABEL
PROP LOSS CURVE
NUMBER OF CONVERGENCE ZONES
CONVERGENCE ZONE ONSET RANGE (if NUMBER OF CZ's GT 0)
CONVERGENCE ZONE WIDTH (if NUMBER OF CZ's GT 0)
(last 2 parameters repeated by NUMBER OF CONVERGENCE ZONES)
(last 5 parameters repeated by NUMBER OF PROP LOSS CURVES)

CATEGORY 6: STATISTICAL PARAMETERS
RANDOM NUMBER SEED
BUOY-TO-BUOY FOM FLUCTUATION STANDARD DEVIATION
HOLDING AREA TARGET DISTRIBUTION (if TARGET MOVEMENT = HOLDING)
CENTER OF HOLDING AREA, X COORDINATE (if HOLDING AREA DISTRIBUTION = NORMAL)
HOLDING AREA STANDARD DEVIATION, X DIRECTION (if HOLDING AREA DISTRIBUTION = NORMAL)
CENTER OF HOLDING AREA, Y COORDINATE (if HOLDING AREA DISTRIBUTION = NORMAL)
HOLDING AREA STANDARD DEVIATION Y DIRECTION (if HOLDING AREA DISTRIBUTION = NORMAL)

CATEGORY 7: TACTICS SELECTION
NUMBER OF TACTICS TO CONSIDER
TACTIC I.D. NUMBER (if NUMBER OF TACTICS GT 0)
(last parameter repeated by NUMBER OF TACTICS)
NUMBER OF BUOY SPACINGS
MINIMUM BUOY SPACING
MAXIMUM BUOY SPACING
MIN NUMBER OF BUOYS (if NUMBER OF TACTICS = 0)
MAX NUMBER OF BUOYS (if NUMBER OF TACTICS = 0)

CATEGORY 8: TACTIC DEPTH SCHEDULE ASSIGNMENT

(if NUMBER OF PROP LOSS CURVES GT 1)

NUMBER OF TACTICS RECEIVING DEPTH SCHEDULES

I.D. NUMBER OF TACTIC TO RECEIVE DEPTH SCHEDULE

NUMBER OF SCHEDULES FOR THIS TACTIC

NUMBER OF BUOYS IN THIS TACTIC

DEPTH SCHEDULE FOR THIS TACTIC

(last parameter repeated by NUMBER OF SCHEDULES)

(last 4 parameters repeated by NUMBER OF TACTICS RECEIVING DEPTH SCHEDULES)

CATEGORY 9: OUTPUT SELECTION

FLAG FOR QUICK RUN

SCALE OF CUMULATIVE PROBABILITY TABLE (if FLAG FOR QUICK RUN = QUICK)

15.0 TASK FORCE AREA COVERAGE PREDICTION SYSTEM (TAPS)

The TAPS model computes and displays areas of detection coverage provided by AN/SQR-18 Tactical Towed Array System (TACTAS), AN/SQR-15 Towed Array Surveillance System (TASS), and fields of omnidirectional sonobuoys in a task force environment. TAPS also simulates the counterdetection performance of a Soviet submarine sonar against the task force. TAPS is intended as an aid to ASW decision makers at the ASW Commander and Task Force Commander levels to coordinate the disposition of units and use of passive acoustic resources to satisfy mission objectives.

TAPS uses propagation loss generated by the FACT model in its sensor performance calculations. The model examines the intermediate file, Z999ICAPS:IM, to determine if the needed propagation loss values are available. TAPS makes internal calls to the FACT model to automatically calculate all additional propagation loss values required to predict the performance of all assigned sensors against the designated threat. In preparation for a TAPS run it is necessary only to make certain that PROFGEN or GENRAYT has generated the appropriate environment in the intermediate file. TAPS will take care of having FACT produce the required propagation loss values. TAPS contains files of acoustic signatures (frequencies and source levels) for task force units and threat submarines. See table 15-1 for a list of the ship types and threat submarines for which signatures are stored. The user may select any of the platforms listed in the table, or choose to define different frequency/source level signatures as he designates the makeup of the task force. The signatures of own force units are used for two purposes. They enter the calculations that compute performance of the Soviet submarine sonar for counterdetection predictions. They also factor into the predictions of towed array and sonobuoy cov[illegible]e as noise. Sensor performance in the vicinity of a task force is significantl[illegible]paired by the noise produced by the task force units themselves. Depending on the ship types selected from the table, TAPS computes radiated noise levels approp[illegible]te for the platform speeds at the search frequencies selected.

TABLE 15-1. UNIT TYPE CODES

CODE	SHIP TYPE
1	FF 1097 USS MOINESTER
2	FF 1052 KNOX CLASS
3	FF 1037 BRONSTEIN CLASS & FF 1040 GARCIA CLASS
4	CV (KITTY HAWK CLASS)
5	C[illegible] (BELKNAP CLASS)
6	DD[illegible] (CHARLES ADAMS CLASS)
7	AO [illegible]LERS*
8	AOE FAST COMBAT SUPPORT SHIPS*
9	AFS COMBAT STORE SHIPS*
10	[illegible]P[illegible] AMPHIBIOUS ASSAULT SHIPS*
11	LST TANK LANDING SHIPS*
12	ENEMY (COUNTERDETECTION)
13	SBUOY (SONOBUOY FIELD)

*Radiated noise data have been estimated on the basis of similar ships.

The user defines the task force units with codes from table 15-1, and gives their positions relative to the center of the task force, their speeds, and the sensors assigned. All task force data (ship type, speed, relative position, sensors) are stored in a save file. When TAPS is run again the contents of that file may be used as is, or may be modified. This frees the user from having to completely redefine the task force for each new run of TAPS. TAPS is a static model: the positions of the units always remain the same and are not automatically updated based on input speeds and headings. A special unit type category permits sonobuoy fields to be entered. Any pattern contained in the library file created by the sonobuoy geometry module, GEOMT, of the TASDA model may be selected for TAPS analysis. See section 14.2 for a discussion of GEOMT.

The counterdetection model built into TAPS generates a display of the area surrounding the task force within which a threat submarine can passively detect the presence of the force. Areas of vulnerability can be readily identified by comparing this counterdetection display with the force detection coverage display. Repositioning of sensor platforms or establishing additional sonobuoy fields may be attempted to determine the effectiveness of those tactics at reducing vulnerability.

When all required information on the tactical situation and the environment are provided, TAPS calculates and displays any of the plots shown in figures 15-1 through 15-5. Display scales may be varied, and two probability levels may be displayed simultaneously (figure 15-2). In addition to the area coverage graph, the output display includes run identifiers, a listing of input parameters, percentage probability of detection, and the total area of cells within which the selected detection probability is met or exceeded. Each display contains an 80 x 80 grid of cells; their size depends on the display scale. It should be noted that the noise value in the input box is not the input value for ambient noise, but is the noise on the rear end-fire beam of the array. It thus includes input ambient noise, noise generated by the task force, array self-noise, and directivity of the end-fire beam. The FOM as well is a calculated, and not an input, value.

TAPS has many applications including mission planning, task force routing, and exercise reconstruction. For planning purposes, proposed task force composition may be used with climatological or projected synoptic data on the ocean environment. TAPS is also useful for estimating detection coverage in an ongoing tactical situation and for evaluating the performance of acoustic arrays at various tow depths and speeds in different configurations about the task force. In this manner it serves to optimize the tactical disposition of command assets.

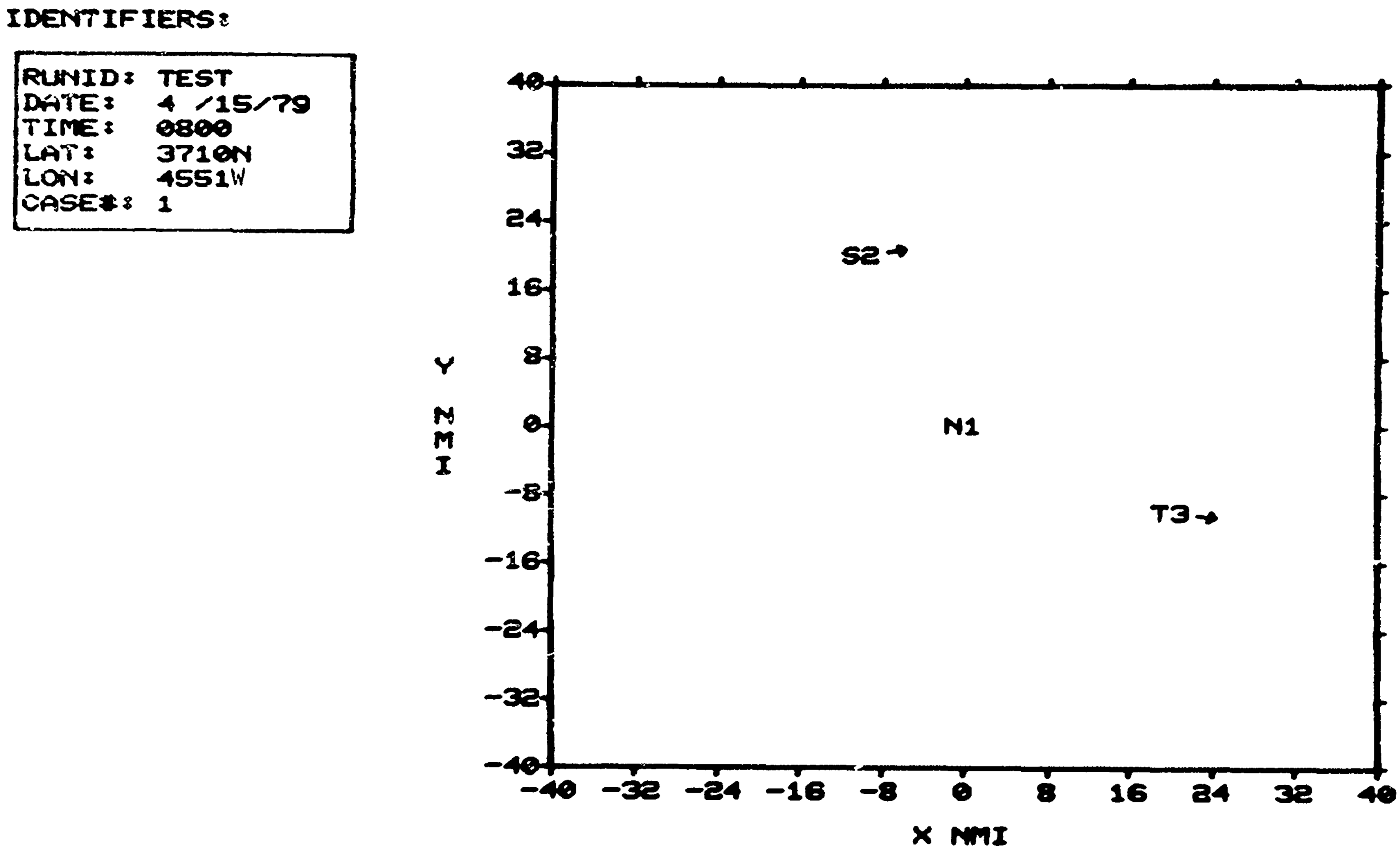

Figure 15-1. Distribution of Force Units

IDENTIFIERS:

RUNID:	TEST
DATE:	4 /15/79
TIME:	0800
LAT:	3710N
LON:	4551W
CASE#:	1

INPUTS:

FREQ(HZ):	150
TDEP(FT):	60
RDEP(FT):	60
S #BEAMS:	23
SL(DB):	160
RD(DB):	0
NOISE(DB):	68
FOM(DB):	92

	PD (%)	AREA (NMI2)
+	80	3424.
·	50	6848.

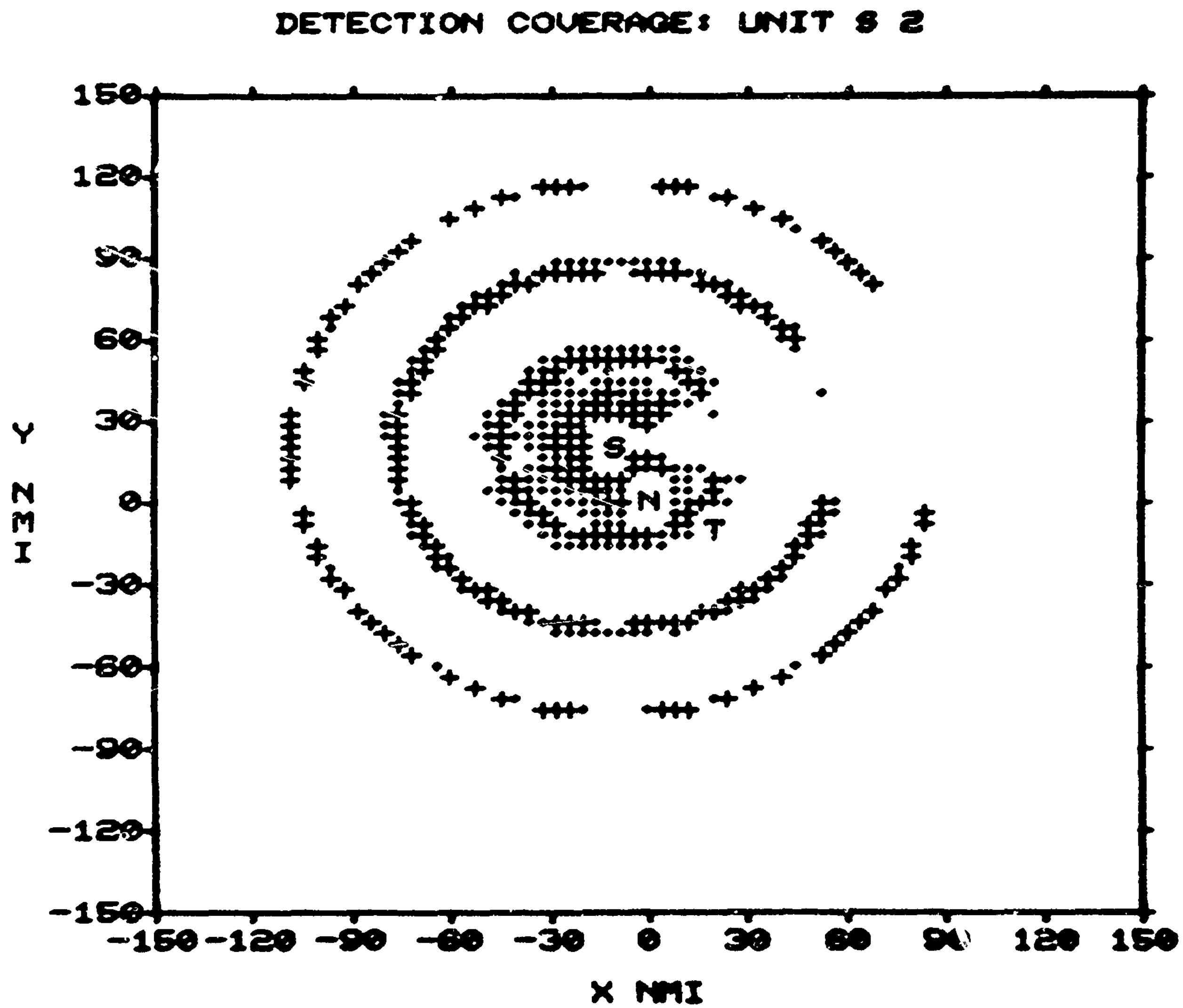

Figure 15-2. TAPS Single Array Detection Coverage

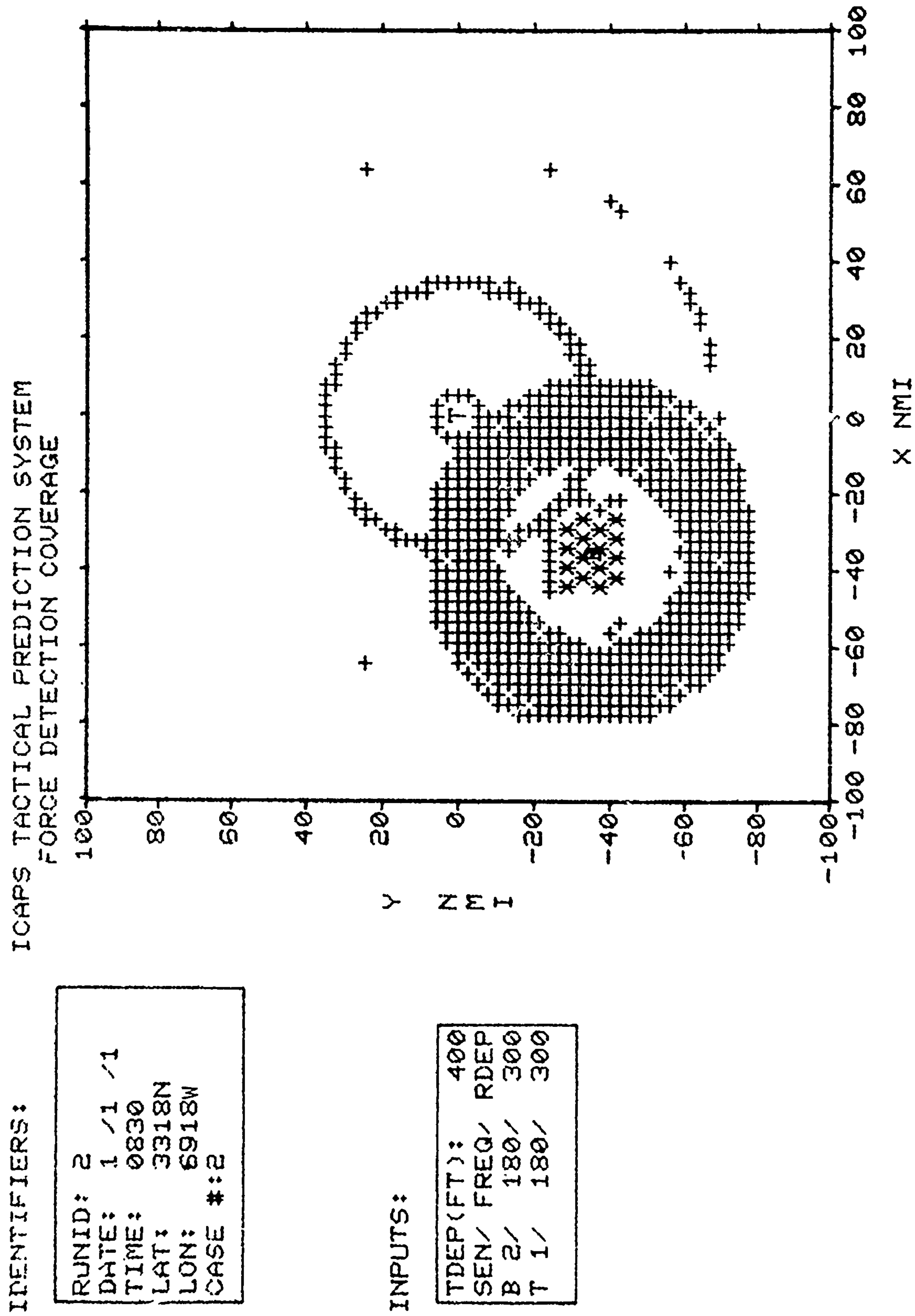

Figure 15-3. TAPS combined detection coverage with TACTAS (T) and sonobuoy field (B).

IDENTIFIERS:

RUNID:	TEST
DATE:	4 /15/79
TIME:	0800
LAT:	3710N
LON:	4551W
CASE#:	1

INPUTS:

FREQ(HZ):	150
TDEP(FT):	60
RDEP(FT):	60
S #BEAMS:	23
T #BEAMS:	8

PD (%)	AREA (NMI2)
+ 20	2688.

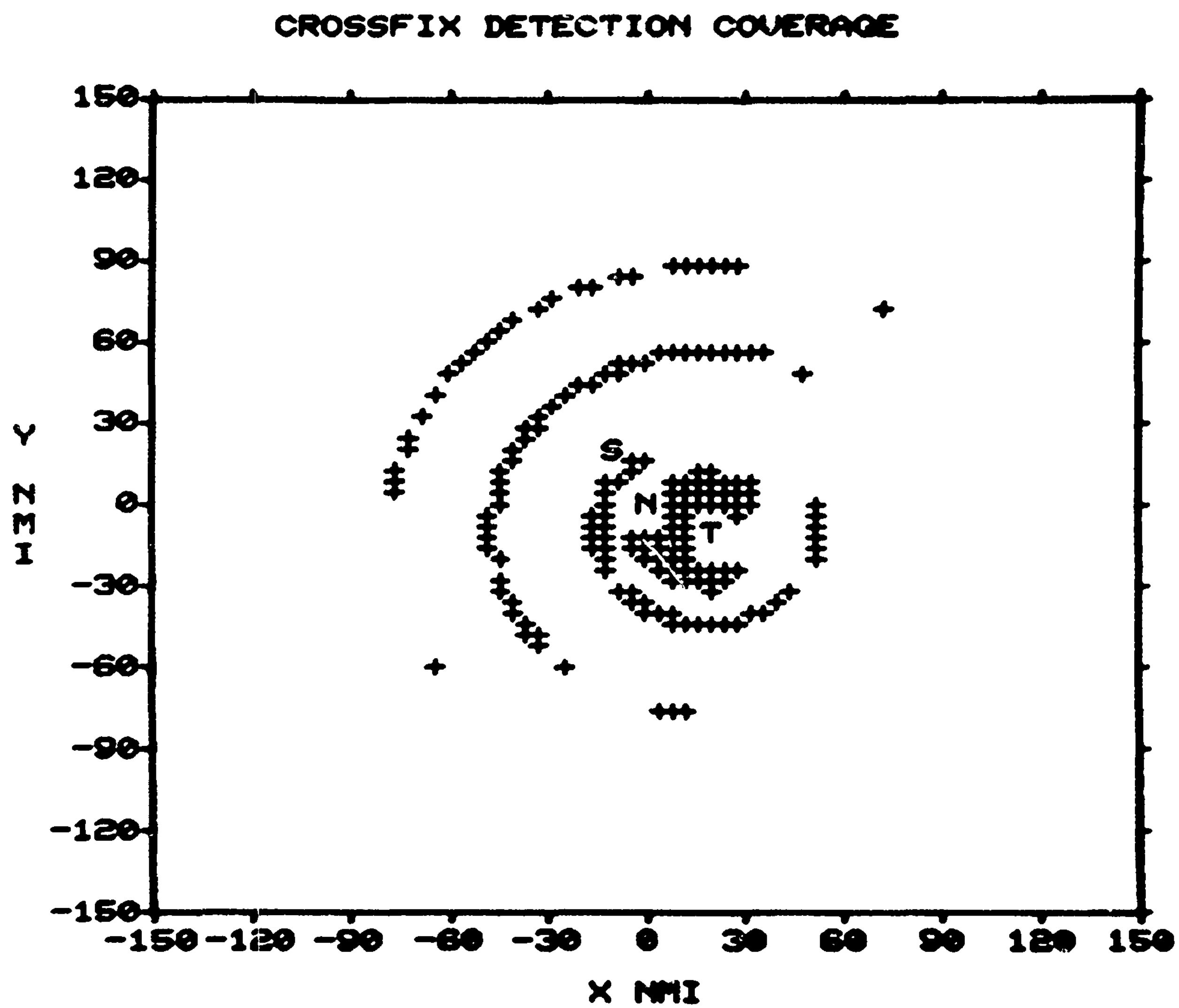

Figure 15-4. TAPS Cross-Fix Coverage

IDENTIFIERS:

RUNID:	123
DATE:	5 /15/82
TIME:	2222
LAT:	3200N
LON:	6500W
CASE #:	1

INPUTS:

TDEP(FT): 400

SEN/	FREQ/	RDEP
B 1/	400/	300
B 2/	400/	300

PD (%)	AREA (NMI2)
+ 50	1316.

ICAPS TACTICAL PREDICTION SYSTEM
FORCE DETECTION COVERAGE

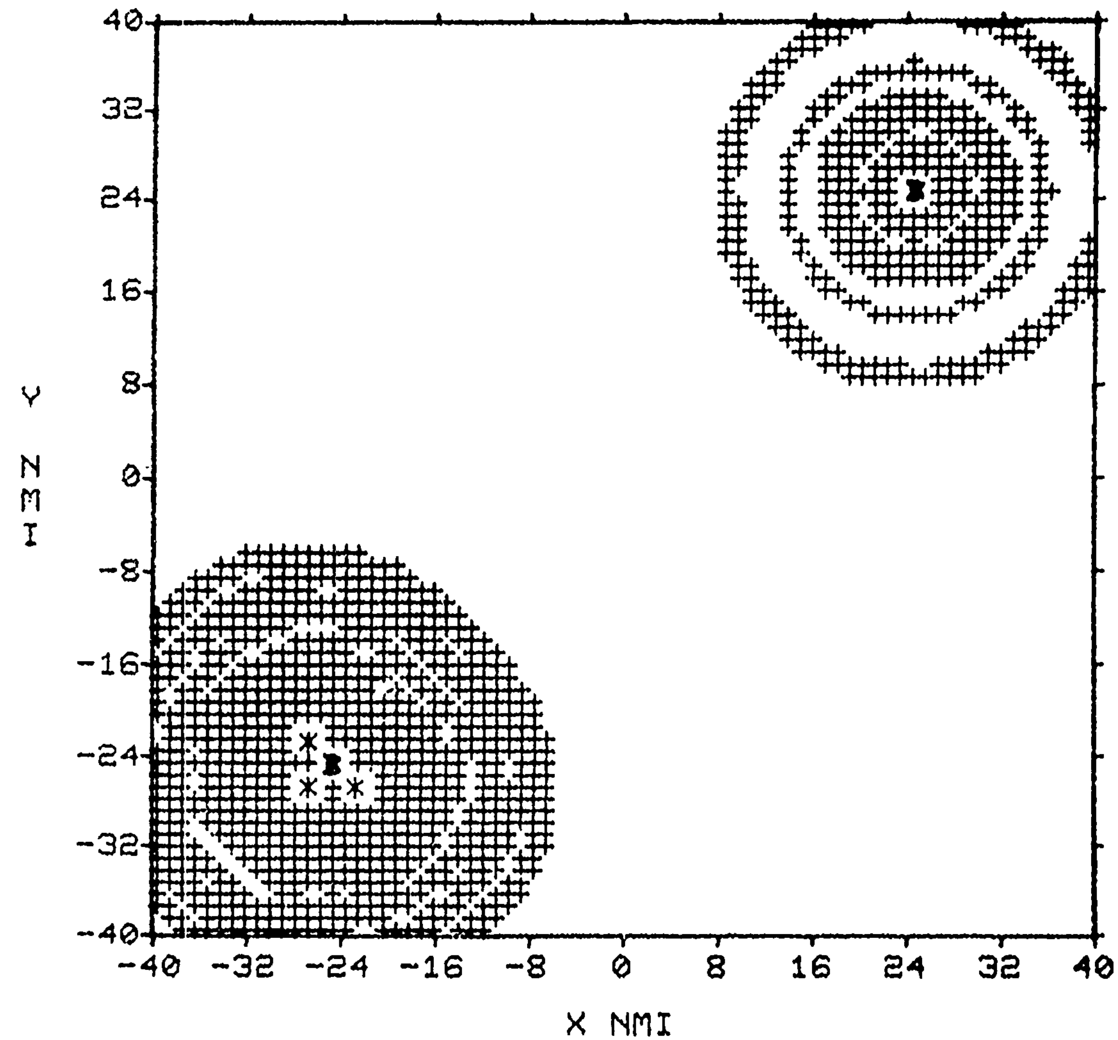

Figure 15-5. TAPS sonobuoy field detection coverage.

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REPORT DOCUMENTATION PAGE

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Change 2 to RP 24, Vol. II, includes a revised Table of Contents and replaces Chapters 3 and 15.

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Barbers Point, HI		2
Bermuda		2
Brunswick, ME		2
Cecil Field, FL		2
Cubi Point, RP		2
Jacksonville, FL		2
Kadena, JA		2
Keflavik, IC		2
Lajes, AZ		2
Misawa, JA		2
Moffett Field, CA		2
North Island, CA		2
Patuxent River, MD		2
Rota, SP		2
Sigonella, IT		2

16.0 COMPUTER ASSISTED SEARCH SERIES (COMPASS) PACKAGE

16.1 GENERAL

This section is a guide to users of the Computer Assisted Search Series Programs, COMPASS II Mod 3. This is the version of COMPASS prepared for use on the NOVA 800 minicomputer. Henceforth, COMPASS II Mod 3 will be shortened to simply COMPASS.

The COMPASS system consists of four programs or modules - DATUM, UPDATE, DETECT, and MAP. The purpose of the COMPASS programs is to aid in the planning of a search by providing estimates of the target's location and motion behavior. The estimates of target location are produced by quantifying the prior knowledge, often subjective, about the target's location. This prior information is combined with current information, both positive and negative, obtained as the search progresses to produce posterior target location and behavior distributions in a Bayesian manner. Based on these posterior distributions, the programs may be used to recommend allocations of new search effort.

The COMPASS programs are a decision aid to help focus search thinking and to evaluate the numerous and complex possibilities that arise during a search. The programs depend on inputs which require careful thought by the user in order to yield the most accurate representation of the search problem. The COMPASS programs are discussed individually later in this section.

The COMPASS programs are Monte Carlo simulation programs in the sense that the target distributions consist of a large number of simulated target points. Typically, 1000 target points are recommended for applications on the NOVA minicomputer. A target point is represented by a vector containing position and velocity information, a weight which is the relative likelihood that the point represents the target's actual position and motion behavior, an inchop (start) time, and an index number to identify the target point's original scenario.

Typical NOVA 800 run times produced by COMPASS programs are on the order of 2 minutes for a DATUM run, 5.5 minutes for an UPDATE run, 1.5 minutes for a DETECT run, and 0.5 minutes for a MAP run for a 1000 target point file. Other factors which affect the UPDATE run time include the number and complexity of the search units (buoy fields or convex search regions) and the number of time steps contained in the update period. The above UPDATE run time figure was based upon the application of a distributed field (16 buoys) search unit with a 4-hour lifetime over a 6-hour update period containing three time steps.

The basic components of the COMPASS operation are

(1) a scenario generator,
(2) a search updater, and
(3) a target probability map display capability.

Scenario generator. The scenario generator in COMPASS provides the capability to generate a probability distribution for the target's initial location. At the same time, initial motion parameters are also defined. Suppose that a submarine is detected within an elliptical search probability area (SPA) with center C and semi-

major axis a, semi-minor axis b, and orientation θ, as shown in Figure 16-1. Based on empirical data, the search planner determines the appropriate parameters corresponding to a bivariate normal distribution to represent the target's actual location.

In many situations, no single simple scenario accounts for all of the prior knowledge about the target's location. There may be a number of pieces of information which could be used to generate the prior distribution, and some of these pieces may be inconsistent with others. In this case, the search planner must give a subjective weight or credence to each of the scenario candidates. The DATUM program can be used to produce an overall initial target location distribution which is a weighted combination of the various scenarios. Each scenario definition contains a set of distribution parameters and a set of motion parameters.

Search updater. The search updater revises the target location distribution for the effects of:

(1) target motion,
(2) negative information (failure to detect), and
(3) positive information (detections with uncertain localization).

When searching for a submarine, the need to account for target motion is obvious. Initial target motion assumptions for each scenario are recorded by the search generator. The UPDATE program may be used to modify the target motion parameters for any scenario, when necessary.

If search effort is placed into an area and the target is not detected, then by Bayes' theorem the probability that the target is located in that area decreases while the corresponding probability increases in the areas in which no search took place. This updating is accomplished in UPDATE by lowering the relative weights of those points which are located inside the search area in which the target was not detected. When the program updates for motion only, the target weights remain the same. Thus, an area of high or low probability will be swept along according to the motion assumptions for the target. In this sense the programs can remember that the points which are presently in a given area have already been searched (or not searched) at a prior time when, due to target motion, they were in another area.

Sometimes even when the target is detected, the search does not end because of the poor localization of the detection. In this case, the DETECT program generates a posterior distribution in a Bayesian fashion using the actual detection information available together with a subjective confidence factor supplied by the user to account for a false target detection. The result of this updating is to increase the overall weight of points that lie near the region where the detection occurred and to decrease the weight of those points which are far away.

Target probability map display capability. The MAP program provides several display options for presenting the current status of the target distribution probability mass. This output can then be studied in order to recommend new search effort.

16.2 DATUM PROGRAM

16.2.1 Target Motion Scenarios

The DATUM program is used to generate initial target location distributions and to record initial target motion scenarios. Often, these initial distributions

result from a single detection such as a SOSUS SPA. However, the program may be used to combine UP TO FIVE pieces of target information and associated motion scenario assumptions to create a single target distribution file. Based on these data, a collection of sample target points is generated. The user may alter the target motion scenarios when running the UPDATE program. Each target location region is weighted by the user according to his subjective feeling about the importance of that piece compared to the other pieces of information.

When selecting initial location distributions, the user should try to anticipate any future target motion requirements in subsequent update sessions. For example, suppose that at some future point in time, the target flow encounters a land mass, or in general, is believed to split at a given juncture. If the user specifies only one initial target distribution and associated motion scenario, then when the land mass is reached, the target motion information could be altered to model only one path around the land mass. That is, it would not be possible to breakup the target points and send some each way. However, if the user creates two identical initial target location distributions (perhaps with different weights), then when the island is encountered, each target scenario could be given new motion information and the target could be routed around different sides of the island.

A target location region can be expressed as one of two distribution types -- a bivariate normal distribution or a uniform distribution over a convex region.

16.2.2 Normal Distributions and Uniform Distributions

The bivariate normal distribution (ellipse) is defined by entering the quantities

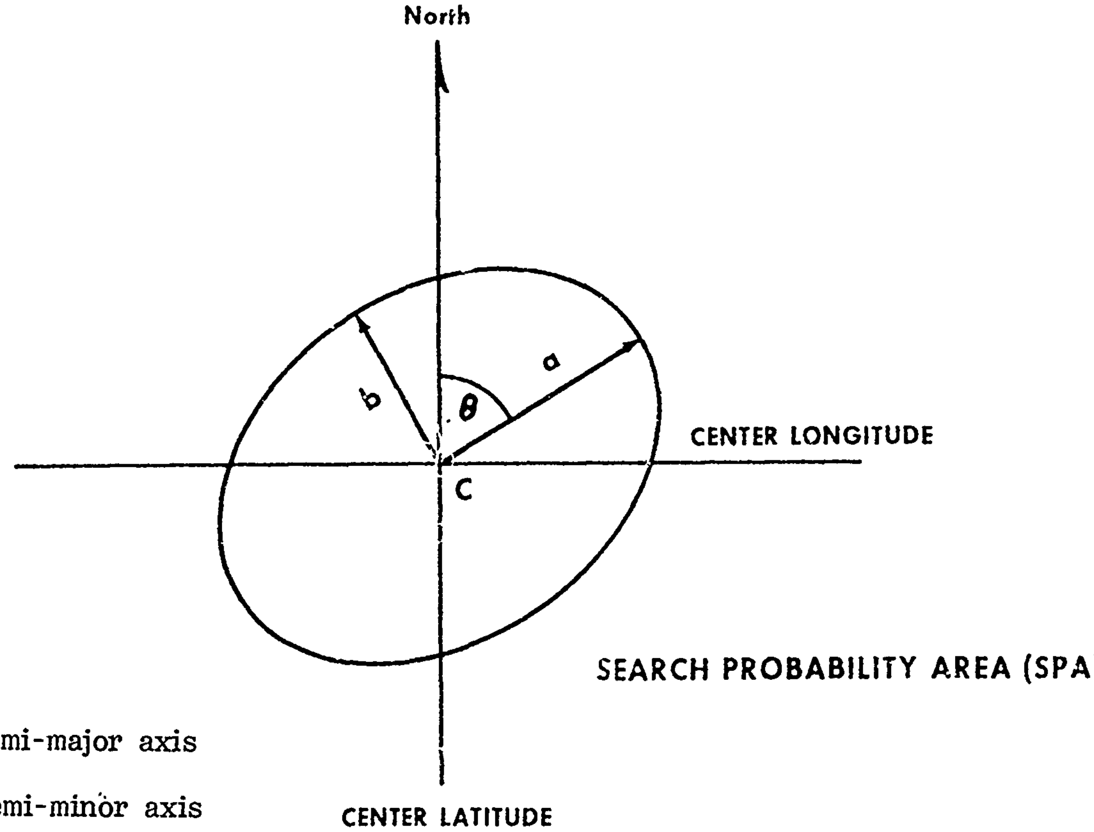
CENTER LATITUDE
CENTER LONGITUDE
SEMI-MAJOR AXIS
SEMI-MINOR AXIS
ORIENTATION

as defined in Figure 16-1. A bivariate normal distribution is frequently used to describe a SOSUS SPA. A uniform distribution can be used when one suspects that the target is located in a region but cannot say whether the target is more likely to be in one part of the region than another. If, however, the target is more likely to be in, say, the eastern half of a given region, then one can model this situation by breaking the region into two subregions as shown in Figure 16-2 and giving the subregion 2 a larger weight than subregion 1. Moreover, a non-convex region can always be broken into two or more convex subregions, with each subregion treated as a separate convex region. The convex region uniform distribution is defined by entering the latitude, longitude pairs for the vertex coordinates in clockwise rotation. The program will accept as many as eight vertices per convex region.

16.2.3 Target File Parameters

The user must assign a target name label to the target distribution. This name may contain up to six alphanumeric characters and will be used by the programs for identifying the current input target file on the screen display. The target name label should not be confused with the target file name.

A reference date time group (DTG) must be assigned to the initial target point distribution created in DATUM. All time quantities appearing in COMPASS output summaries are given in decimal hours relative to the reference time.



a = semi-major axis

b = semi-minor axis

Figure 16-1. Initial Target Distribution from an Elliptical SPA

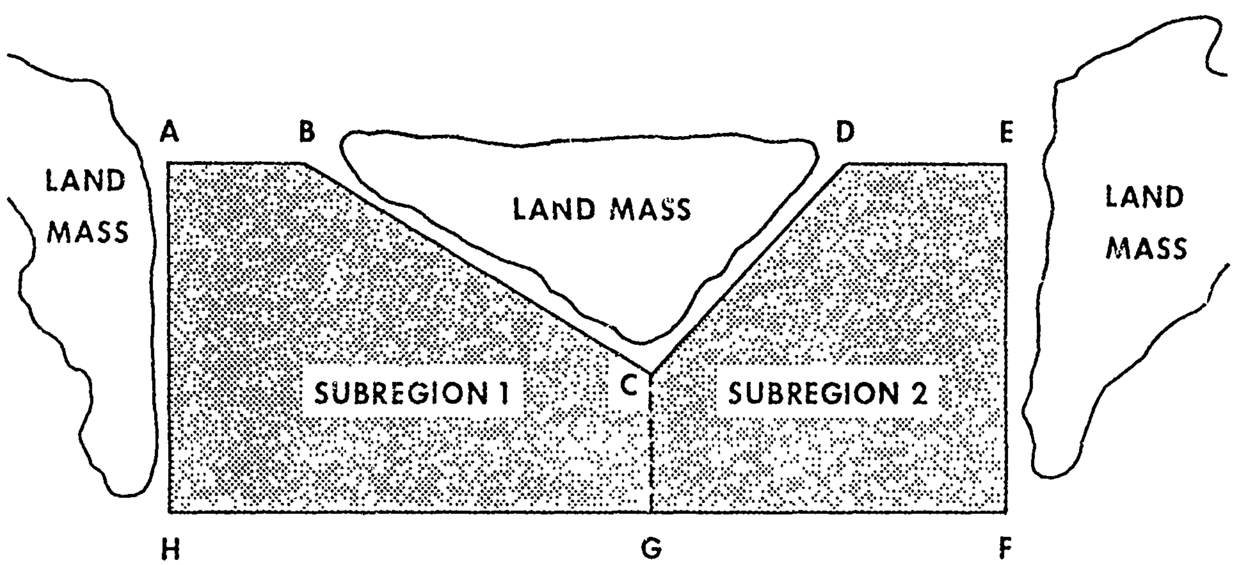


Figure 16-2. Convex Regions Defining a Uniform Distribution

The user must specify a distribution of inchop (start) times for the target points. The term inchop time is a carry-over from Mediterranean operations. This distribution describes the times (relative to the reference DTG) at which the target points will arrive at the initial target distribution. The following quantities must be specified:

minimum time: t_{min}

best time: t_b $(t_{min} < t_b < t_{max})$

maximum time: t_{max}

best inchop time factor: $f_t \leq 1.$

Based on these inputs a truncated triangular distribution for inchop times is created. Distributions of this type are discussed in the next section.

Finally, the total number of target points to be generated must be specified. Normally, one should request roughly 1000 target points. These target points will be apportioned to the number of regions requested in proportion to the region weights.

16.3 INITIAL TARGET MOTION SCENARIOS

The user will be prompted for motion scenario data to be associated with each target location distribution specified. Thus, a region weight may be interpreted as a motion scenario weight. A motion scenario consists of a range of eligible courses and speeds for the target. The user must specify the following quantities for each motion scenario.

average time on leg: t_{LEG}

low course: θ_1

best course: θ_b $(\theta_1 < \theta_b < \theta_u)$

high course: θ_u

best course weight factor: $f_C \geq 1$

course variation: Δ_C

low speed: V_1

best speed: V_b $(V_1 < V_b < V_u)$

high speed: V_u

best speed weight factor: $f_S \geq 1$

speed variation: Δ_S

If a target point were located at position P at time 0 and traveled for a time T ($T \ll_{LEG}$) according to the motion scenario indicated in Figure 16-3 then its fan of possible positions would consist of the shaded region indicated.

If the user feels that within the range of speeds V_1 to V_u all speeds are equally likely, then he can choose any value for V_b such that $V_1 < V_b < V_u$ and set the best speed weight factor $f_S = 1.0$. If the user feels that within the range V_1 to V_u there is a speed which is distinctly more likely than the others he can set V_b equal to that speed and adjust its f_S value appropriately. This would produce a truncated triangular distribution on speeds, as indicated in Figure 16-4. Thus, speeds close to V_b are more likely to be selected than those away from V_b. More specifically, the speed range $[V_3, V_4]$ should produce approximately B/A times as many target point speed values as the speed range $[V_1, V_2]$. In any case, $f_S \geq 1.0$.

The specification of the distribution of courses proceeds in a similar fashion. The program assumes that the sector of directions opens clockwise from θ_1 to θ_u. Thus, if one enters $\theta_1 = 340$ and $\theta_u = 040$, he would obtain the same sector of directions produced by entering $\theta_1 = 020$ and $\theta_u = 040$.

A random draw from the given distributions will determine the base course and speed to be associated with each target point. The program allows for variations about the base course and speed. The target point base course and speed are modified with variations uniformly between $\pm\,\Delta_C$ and $\pm\,\Delta_S$ respectively each time the target point starts on a new leg. The duration of each new leg is a random variable based upon the user input--average time on leg. The program is designed so that the average course and speed of advance of the target over a significant period of time are determined by the <u>base</u> course and speed, and are not affected by the variations.

The program advances each target point along its path at discrete time increments for the duration of the update period. The time step, selected by the user, together with the best speed selection determine the nominal distance covered by the target point during the time step. This is a critical consideration when updating for search because the effects of search are computed using the target point position at the end of each time step. When the target point reaches the end of a leg with a fractional time step remaining, the time difference is applied along the new leg. There will be more about the time step later. Figure 16-5 shows a motion update sketch for a single target point.

16.4 UPDATE PROGRAM

This program is designed to update the target file for the effects of target motion and expended search effort which has failed to detect the target. The user must specify the length of time in decimal hours since the last operational event. This is referred to as the update period. The time step, which is discussed below, must also be specified and should evenly divide the update period.

16.4.1 <u>Updating Motion Information</u>

The UPDATE program begins by allowing the user to review and, if desired, alter the motion scenarios. In response to the prompt SPECIFY BASE COURSE, the user answers O if the old motion scenarios are still valid, N if new motion scenarios are to be defined, and S if he wishes to see a summary of the current motion scenario parameters. If one or more new motion scenarios are required, the prompts and inputs are identical to those which appeared in DATUM.

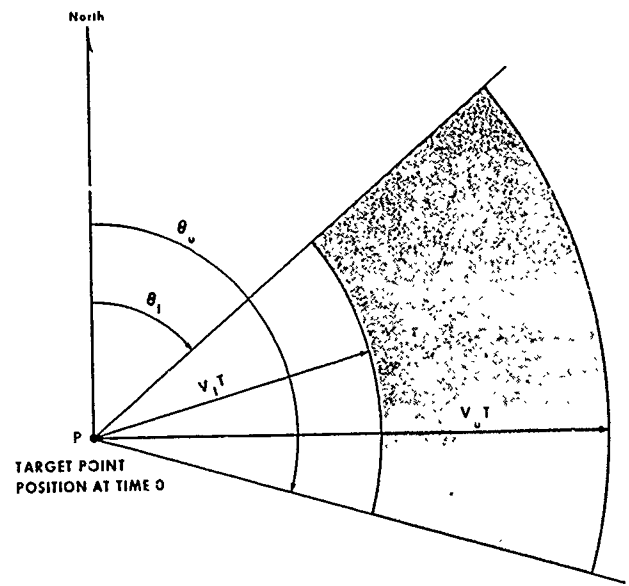


Figure 16-3. Fan of Possible Target Positions at Time T

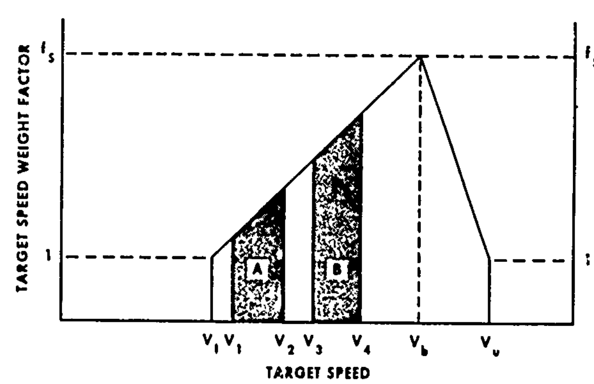


Figure 16-4. Truncated Triangular Distribution on Target Speeds

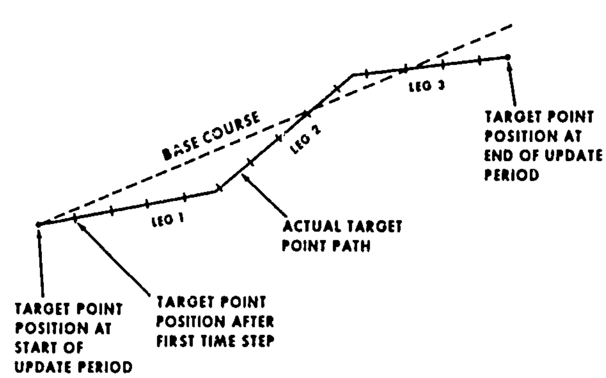


Figure 16-5. Example of Target Point Motion

Once the motion scenarios have been reviewed and confirmed, they will remain intact until such time as the user decides to modify them in a subsequent UPDATE session.

16.4.2 Updating for Failure to Detect

The UPDATE program is also designed to update target files for search effort which has failed to detect the target. If the user wishes to update for search, he enters an affirmative response to the prompt DO YOU WANT TO UPDATE FOR SEARCH?. The search units simulated in the UPDATE program refer to two types of search effort--buoy fields and convex search regions.

The user may define as many as three buoy fields and five convex regions. Each search unit definition includes time-on and time-off values which should coincide (at least roughly) with an integer time step. Figure 16-6 provides an illustrative sketch of several search unit operating periods. The search update calculations are performed only at the endpoints of the time step intervals. Thus, the time step selection should also take into account the average distance covered by a target point during one time step and should be small enough to avoid the situation in which a target point may "step over" a region rich in detection probability, e.g., a convergence zone. On the other hand, to avoid unreasonably lengthy run times, the time step should not be selected smaller than necessary. Figure 16-6 indicates the operating periods of five search units for a single update period, T. The time steps are indicated by the hash marks on the time line. Note that all time-on and time-off values coincide with integer values of time step. For the user's convenience, a time-on value may be less than the start time of the update period, and a time-off value may be greater than the end time of the update period, but search update is applied only within the update period.

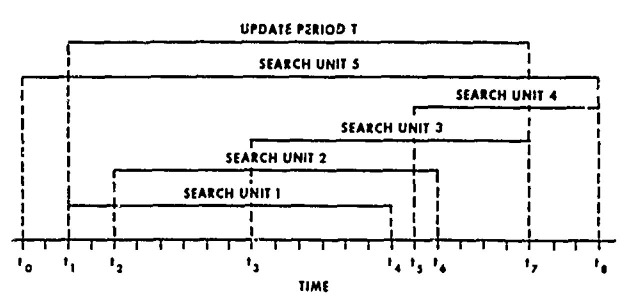


Figure 16-6. Search Unit Operating Periods.

Propagation loss data for the operating environment are required when the user selects a buoy field search unit. The user may specify any of the current propagation loss curves contained in the ICAPS file, or he may define an ad hoc propagation loss curve simply by entering direct path and convergence zone information. Figure 16-7 describes the MDR, CZ propagation loss curve construction. The propagation loss curve defined by the MDR, CZ option is actually a probability of detection versus range curve. For that matter, every propagation loss curve used by program UPDATE is first converted to this form. The MDR, CZ curve may consist of one, two or three exponential contributions of the composite result. The median detection range (MDR) is defined as the direct path range at which probability of detection equals 0.5. If the user selects MDR less than 1, there

will be no direct path contribution to the curve. P_0 is the detection probability at range 0. P_0 must be greater than 0.5. R_{CZ1} and R_{CZ2} are the nominal mid-range values of the convergence zones, P_{CZ_1} and P_{CZ_2} are the associated detection probabilities, and W_{CZ1} and W_{CZ2} are the associated convergence zone widths. The convergence zone width is defined as indicated in the figure. The user may select zero, one, or two convergence zone contributions to the curve.

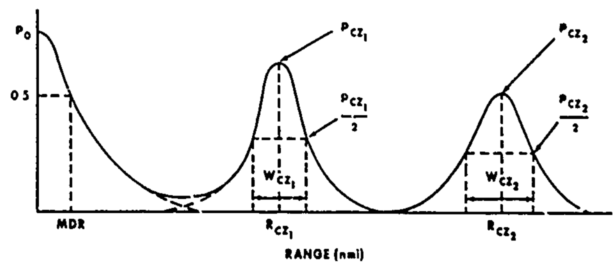


Figure 16-7. MDR, CZ Construction of Propagation Loss Curve.

16.4.3 Buoy Fields

For the user's convenience the UPDATE program provides four buoy field input options:

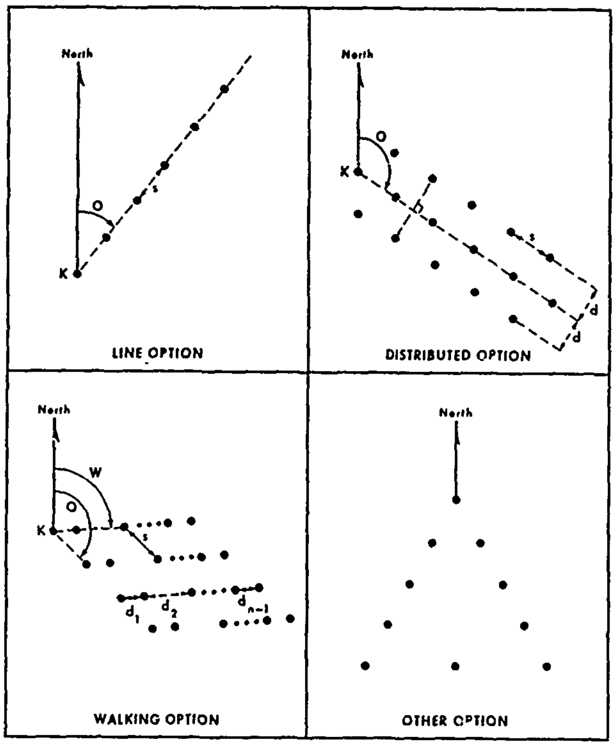
L - line barrier
D - distributed field
W - walking barrier
O - other

With the exception of the distributed field which contains the popular 5-6-5 buoy configuration, each buoy field may contain as many as 32 buoys. The O-option is used when it becomes necessary to identify each buoy location individually. Figure 16-8 shows sketches of the buoy field configurations and parameters associated with the four options.

The user must enter a time-on (in hours relative to start of update period) and a lifetime (in hours) for each buoy field. The entire buoy field is assumed to be operative, without failure, throughout the lifetime. The user must designate a propagation loss curve to represent the buoy field environment. A single value of buoy figure of merit, supplied by the user, is assigned to each buoy in the buoy field. Buoy placement error may be taken into account by entering a positive value in response to the prompt SPECIFY BUCY PLACEMENT ERROR SIGMA. The buoy placement error option (if used) will require an immediate computational run time of 2.5 minutes with the MDR, CZ propagation loss data and as much as 7.5 minutes with ICAPS data.

16.4.4 Convex Regions

The user may wish to describe the search unit as a convex region with uniform probability of detection p for a target point which spends three hours within the region. Equivalently, a target point which spends three hours in the region would fail to be detected with probability 1-p. If the target point is outside the



Buoy Field Input Parameters	LINE	DISTRIBUTED	WALKING	OTHER
Number of buoys	X			X
Coordinates of kingpin K	X	X	X	
Orientation O of kingpin row	X	X	X	
Buoy spacing s	X	X	X	
Row spacing d		X		
Walk bearing W			X	
Number of rows n			X	
Number of buoys per row			X	
Distance d_i along walk			X	
Individual buoy coordinates				X

Figure 16-8. Buoy Field Input Options

region for the three hours, the failure probability for that point will be 1.0. If the target point is inside the region for some amount of time between 0 and 3 hours, the failure probability is exponentially interpolated between 1.0 and 1-p. The UPDATE program multiplies the weight of each target point by the calculated failure probability. Thus, those points which are in the field the longest will have their weights lowered the most.

For the user's convenience, the UPDATE program provides two convex region input options:

K - kingpin data
V - vertex data.

The K-option is used to describe a rectangular region with depth D, width W, and orientation O, as indicated in Figure 16-9. Also required are the locations of a virtual kingpin K and the probability of detection p within the rectangle. The V-option permits the user to describe a general convex region by entering the geographical coordinates of its vertices. A maximum of 8 vertices may be used. Again, the probability of detection p within the convex region must be specified. The discussion regarding on-off time for the buoy fields also applies to the convex regions.

16.4.5 Search Effectiveness Probability

The results of the negative search update are described by the quantities single search effectiveness probability (SSEP) and cumulative search effectiveness probability (CSEP). SSEP is the probability that the search accounted for in the last update would detect the target provided that a large number of searches identical to the present one were performed. CSEP is the probability that all search applied since the last detection, or since the start of search if no detection has been made,

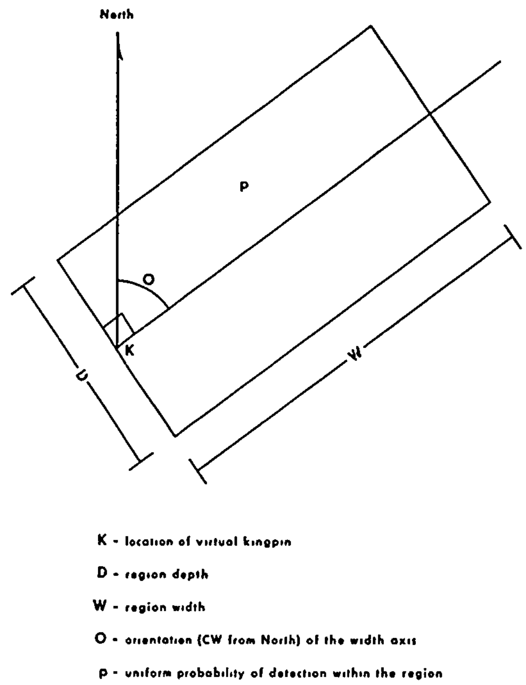


Figure 16-9. Convex Region Using Kingpin Data Option

would have detected the target. Moreover, the user has the option either to preserve the CSEP intact or to reset the CSEP to zero when updating the target file for a detection. Thus, SSEP and CSEP provide a measure of the effectiveness of the search effort.

16.5 DETECT PROGRAM

The DETECT program is used to update the target distribution file for positive information, in particular, a reported target contact. The program will accept descriptions for as many as five simultaneous contacts. If more than one contact is specified, the contacts are treated as independent events.

A false target capability is provided in the sense that the user may enter a confidence factor f, which is a subjective probability that the contact or contacts defined are actually on the target of interest. The effect of this input is to cause the resulting target distribution to be an average of two distributions. The first distribution is the one which would be obtained by assuming the contacts are on the target; the second distribution is obtained by assuming the contacts are false. The resulting distribution is a weighted average of the distributions in the proportion f to 1-f. The target file should first be updated to the time of detection for motion and search, using the UPDATE program. The DETECT program transforms a target distribution from a pre-detect state to a post-detect state at the moment of detection. It was not designed to update the target file for motion or search. The current value of cumulative search effectiveness probability may be preserved intact by responding in the negative to the prompt DO YOU WANT TO RESET CSEP TO ZERO?.

The positive information can be categorized into four types of contact options as follows:

B - bearing
O - omnidirectional
N - normal distribution
C - convex region.

16.5.1. Bearing Contact

The general bearing contact description may consist of a primary bearing β_1 and a secondary bearing β_2. Often, there is but one detection bearing from the sensor location to the target. For a SOSUS bearing contact, however, there may exist a significant probability that the true bearing is actually produced by a back-beam, resulting in a secondary bearing β_2 which is the mirror image of the primary bearing with respect to the SOSUS array orientation. Both β_1 and β_2 are measured clockwise from North. In either case, the user indicates bearing resolution by specifying a single bearing sigma value. If a primary bearing probability value greater than 0.99 is entered, the program will assume a single line of bearing. Range consideration may be incorporated into the detection update calculations by designating a propagation loss curve (from the ICAPS file or from an MDR, CZ construction) to describe the sensor environment. If the user selects the ICAPS file, he must also enter the figure of merit for the sensor. In describing any contact, the user enters a sensor identification label (maximum 4 characters). Sonobuoy placement error can be taken into account by entering a positive value in response to the prompt SPECIFY BUOY PLACEMENT ERROR SIGMA. The buoy placement error option (if used) will require an immediate computational run time of 2.5 minutes with the MDR, CZ propagation loss data and as much as 7.5 minutes with ICAPS data. Target points off the nominal bearing will suffer weight reductions proportional to a normal distribution decay. When range consideration is applied, the weight of each target point is further reduced by a factor proportional to the detection probability at its range from the contact center.

16.5.2 Omnidirectional Contact

The omnidirectional contact description consists of the sensor label, sensor coordinates, sensor placement error, sensor figure of merit, and a propagation loss curve designation. The discussion regarding these inputs is identical to that given for the bearing contact. The weight of each target point will be reduced by a factor proportional to the detection probability at its range from the contact center.

16.5.3 Normal Distribution Contact

The normal distribution contact description consists of the contact label (for display purposes only), and the bivariate normal distribution parameters. Target points away from the contact center will suffer weight reductions proportional to a bivariate normal decay.

16.5.4 Convex Region Contact

The convex region contact description consists of the contact label (for display purposes only), and the region vertex coordinates, entered in clockwise order. The convex region contact serves as a cookie-cutter to the target distribution in the sense that target points within the region are maintained intact whereas target

points outside the region are eliminated. A word of caution - the application of two or more disjoint convex region contacts would wipe out the entire target distribution.

16.5.5 Target Point Regeneration

In general, the detection procedure will produce extremely small target weights for those target points away from the contact center. Because the important result of the detection application is the relative target point weights, not the absolute target point weights, the detection phase is immediately followed by a regeneration phase which attempts to split each target point into several copies, based upon its relative target weight. Many of the target points with very low relative weights will produce no regenerated copies at all and will be discarded. All regenerated target point copies will be assigned the same weight value.

Consider three target points A, B, and C with post-detection weights .0001, .0002, and .001, respectively. The regeneration procedure might produce five copies of point C, one copy of point B, and a 50-50 chance for one copy of point A. The nominal value (typically 1000) for the total number of regenerated target point copies is controlled by the user in response to the prompt SPECIFY NUMBER OF TARGET POINTS AFTER REGEN. The regeneration procedure guarantees a minimum of n target point copies for each scenario in the target file, when n equals 0.2 percent of the nominal regenerated target point copy total. This protects against the possible elimination of an entire detection summary display showing the target point count and weight by scenario index before and after the detection.

16.6 MAP PROGRAM

The MAP program is used primarily to produce target probability maps for a given target file. MAP also provides summaries of the current target file statistics and allows the creation of duplicate target files. There are three basic MAP displays, namely

quick map
detailed map
top probability cells.

The quick map and detailed map are probability maps of the target's location.

16.6.1 Map Display Options

The quick map is a compact map display, providing the target distribution complexion at a glance. It uses a single character (symbol) to represent cell location as well as cell probability. The quick map employs a legend consisting of four symbols to describe the non-void probability cells. Each symbol represents a range percentage of the mode probability. (The highest cell probability is referred to as the mode probability.) The symbols X, *, +, - indicate percentage mode probability ranges 50%-100%, 20%-50%, 5%-20%, and 0%-5%, respectively. The quick map center is indicated by the two C symbols, and the cell size is expressed in minutes.

The detailed map uses a cellular format (not displayed to scale) with latitude and longitude line indicators at each cell width interval. The actual target location probability within each cell is displayed using a 2-digit field (e.g., a probability value of .23549 would appear as 24, and a probability value of .00426 would appear as 0). In general, the detailed map in its entirety will require several sections. A PAUSE message will appear after each section.

The top probability cells option can be used to list the top n probability cells, where $n \leq 50$. The output for this option includes the top cells in order, their locations, their probabilities, and a running cumulative probability total.

17.0 CONCLUSION

The ICAPS programs form an integrated series of mission software designed to process raw environmental data into acoustic, sensor performance, and tactics assessment information useful to the ASW tactical decision maker. The guidance provided in this document enhances the user's ability to generate the best available products from ICAPS.

APPENDIX A: AMBIENT NOISE INTENSITY

Figures

A-1 Ambient Noise Intensity Zones (Atlantic)

A-2 Ambient Noise Intensity Zones (Pacific)

A-3 Ambient Noise Correction Factor

A-4 Mediterranean Locations for FNWC Ambient Noise Estimates

A-5 Ambient Noise Levels for Selected Locations in the Mediterranean (Summer)

A-6 Ambient Noise Levels for Selected Locations in the Mediterranean (Fall)

APPENDIX A: AMBIENT NOISE INTENSITY

Ambient noise is the summation of all sound in the ocean other than that from the target. Sources include wind, waves, shipping traffic, biological activity, and others. Estimates of ambient noise are developed from charts and tables (Figures A-1 and A-2 and Table A-1, for example) which consider geographic location and wave height for the Atlantic and Pacific, from seasonal and geographic curves, as in Figures A-3, A-4, and A-5 for the Mediterranean Sea, or from computer-generated forecast messages. By far the best measure of ambient noise, however, is achieved by on-scene measurement.

The chief contributor to low frequency ambient noise (below 300 Hz) is ship noise resulting from propeller blade cavitation and machinery. At higher frequencies, 300 to 500 Hz, sea state noise begins to dominate. This changing dependency is reflected in the Vidale and Houston (GO Report #4, 1970) method of estimating ambient noise. Table A-1 is entered using the appropriate intensity zone from Figure A-1 or A-2, the observed or forecast significant wave height, and the target frequency. To account for seasonal and geographic variations in the noise contribution from shipping, two interpolations are applied to the noise levels in Table A-1:

(1) Noise levels are higher in winter and lower in summer than the values given in Table A-1. To account for this seasonal variation add the following correction factors, depending on the month:

JAN +1	FEB +2	MAR +1
APR 0	MAY 0	JUN 0
JUL -1	AUG -2	SEP -1
OCT 0	NOV 0	DEC 0

(2) The values in Table A-1 represent the noise level at the center of the zone. A linear interpolation can be applied to obtain values for other locations. For example, the noise intensity at 100 Hz anywhere along the line between zones B and C can be approximated by 75 $\left(\frac{78 + 72}{2}\right)$ dB. Where two intensity values are obtained from the table, one based on the zone (shipping noise) and one on wave height (wind/wave noise), a correction factor must be determined. The difference in dB between the two intensity values is used to enter Figure A-3. The resulting correction factor is then added to the higher of the two values from Table A-1 to achieve the total ambient noise intensity at that frequency arising from both shipping and meteorological sources.

Consider the following example: The value of ambient noise at 100 Hz is desired for the location 40°00'N 40°00'W during August. Significant wave heights of 7 to 8 feet are forecast. The position, found in Figure A-1, falls in intensity zone C, approximately one third of the distance from the center of zone C to the center of zone B. This means that the 100 Hz intensity value for zone C (72 dB) should be more heavily weighted than the value for zone B (78). Thus an appropriate value would be

$$\frac{2 \times 72 + 78}{3} \text{ dB} = 74 \text{ dB}.$$

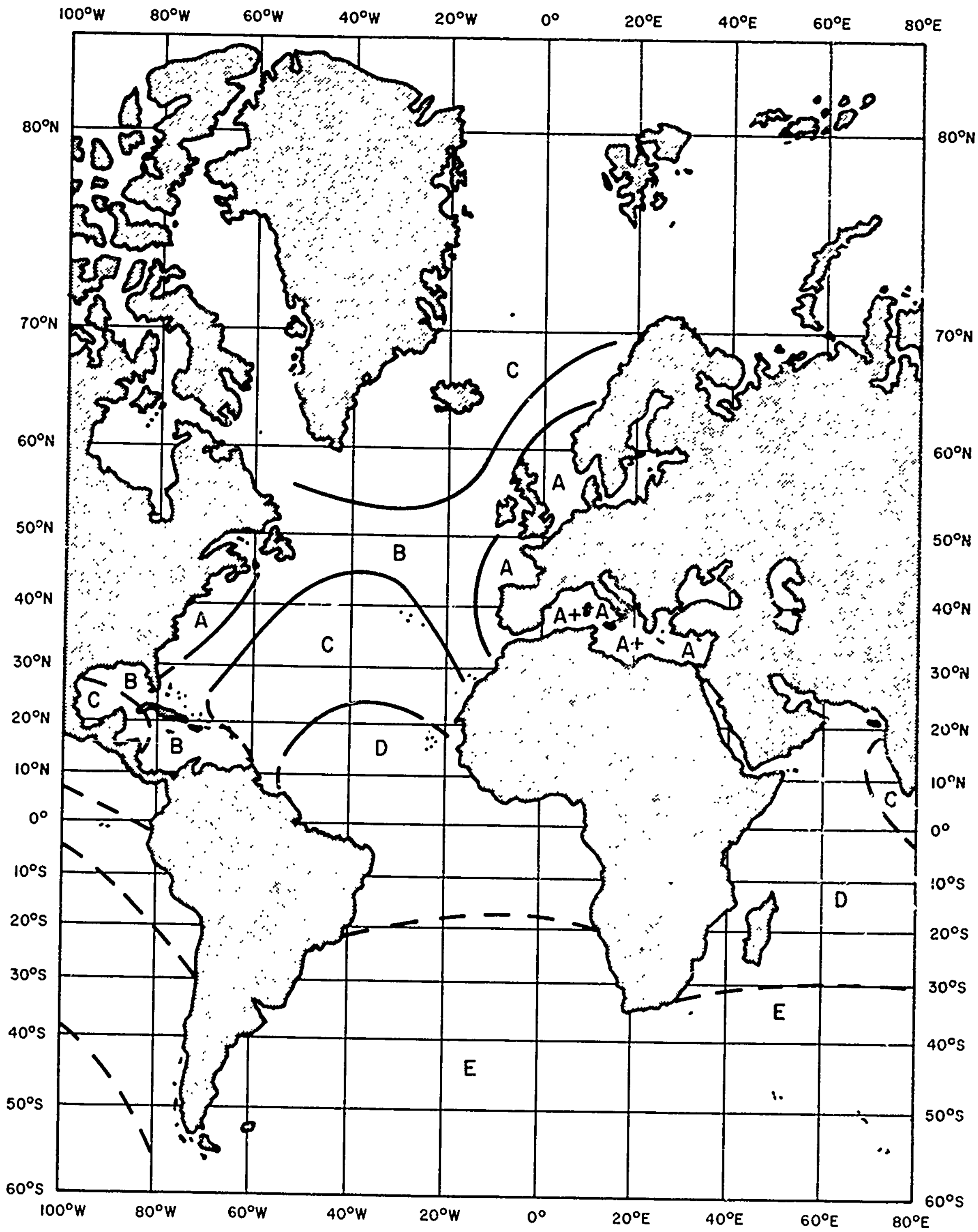


Figure A-1. Ambient Noise Intensity Zones (Atlantic)

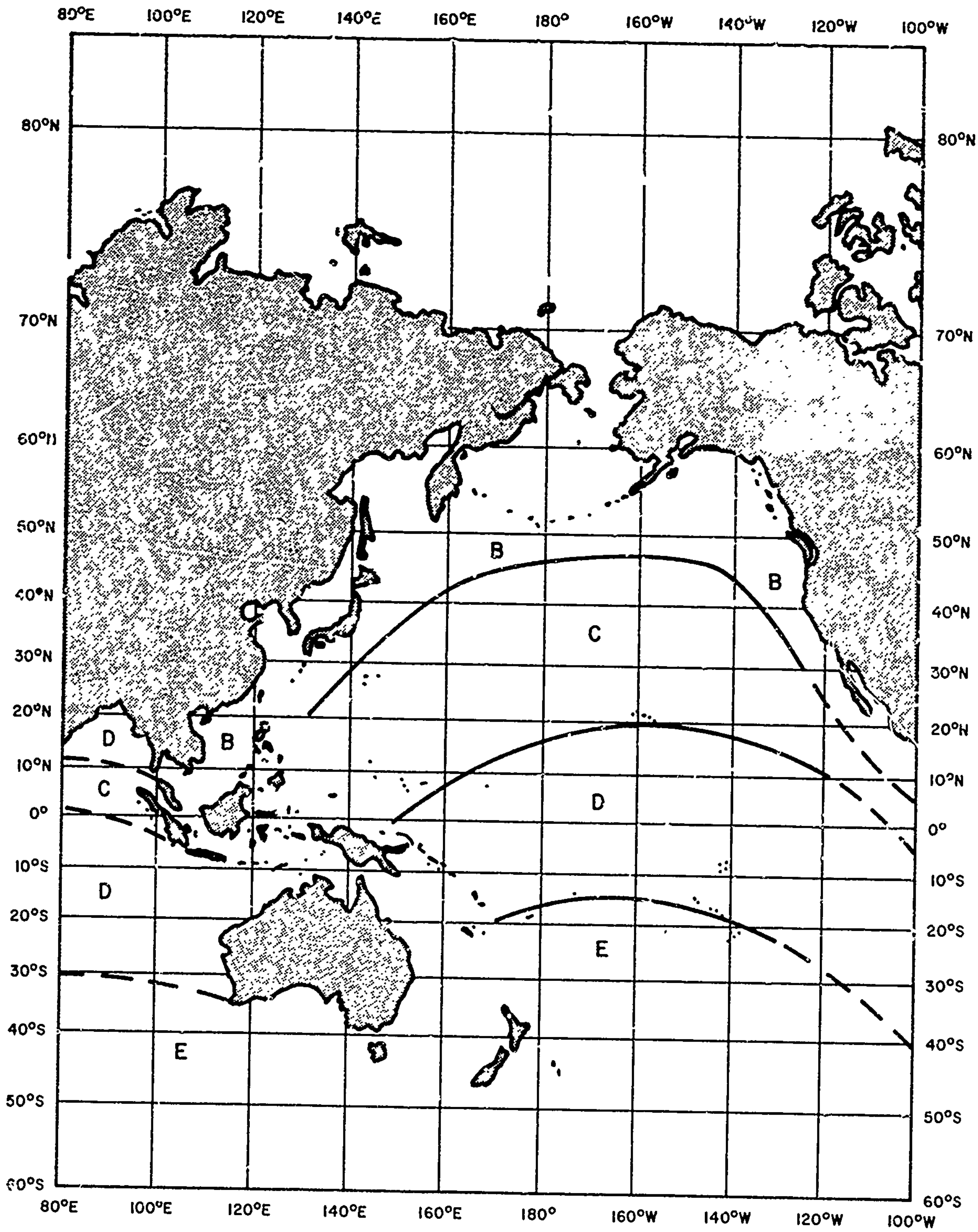


Figure A-2. Ambient Noise Intensity Zones (Pacific)

TABLE A-1. Background Noise Levels (dB re 1 μPa)

FREQUENCY (Hz)	INTENSITY ZONE						SIGNIFICANT WAVE HEIGHT (FT)				
	A+	A		C	D	E	0	1	2	7	11
30	95	85	80	77	72	68	use		intensity		
50	97	87	82	77	72	67					zones
100	92	84	78	72	66	60			62	65	68
200	85	76	70	63	55		51	58	63	66	70
300	80	71	65	57	use		50	58	62	67	71
440	75	67	58		wave		49	56	62	66	71
500	74	64	56		height		48	56	61	66	71
1000	65	52			values		45	53	59	65	70

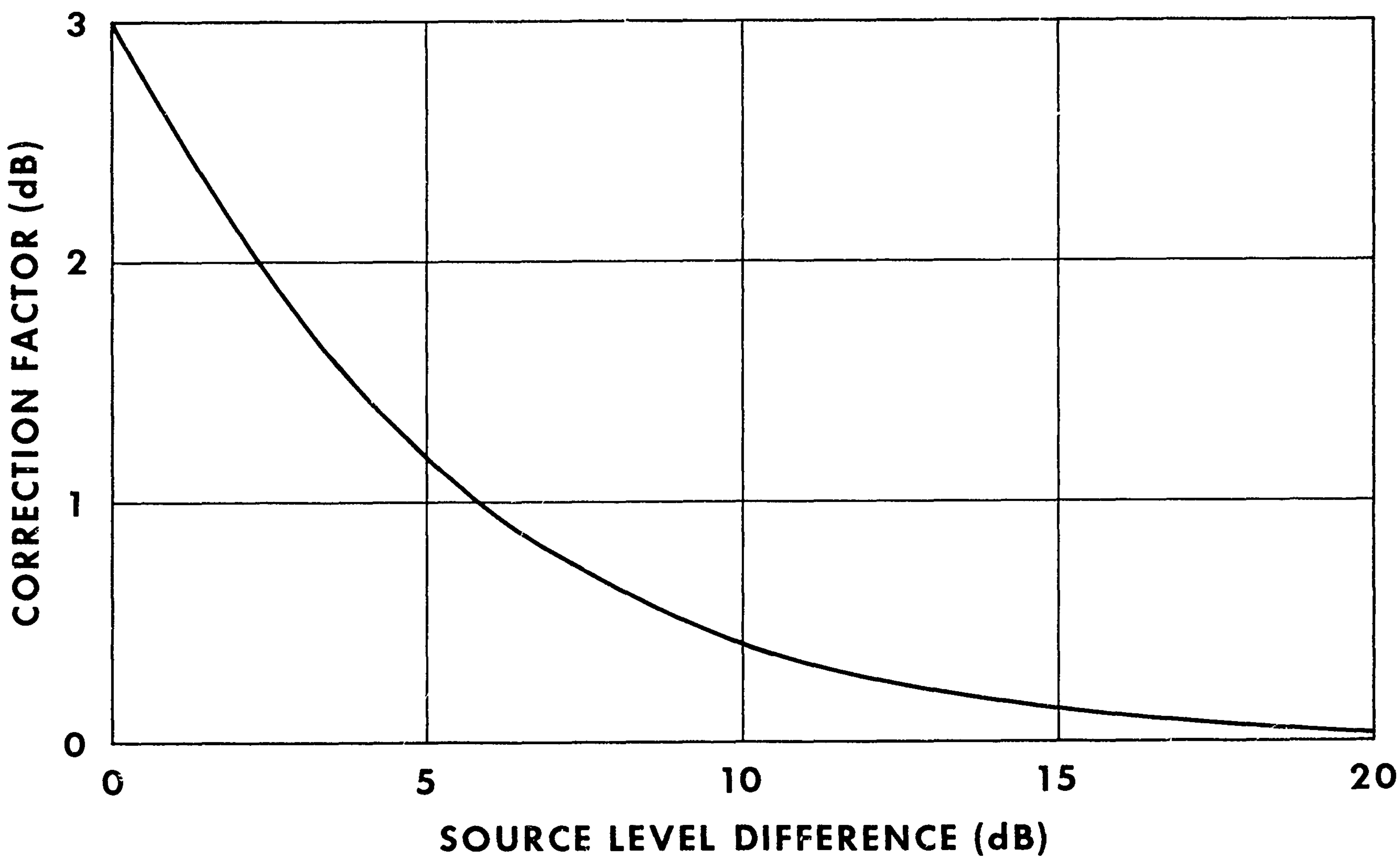


Figure A-3. Ambient Noise Correction Factor

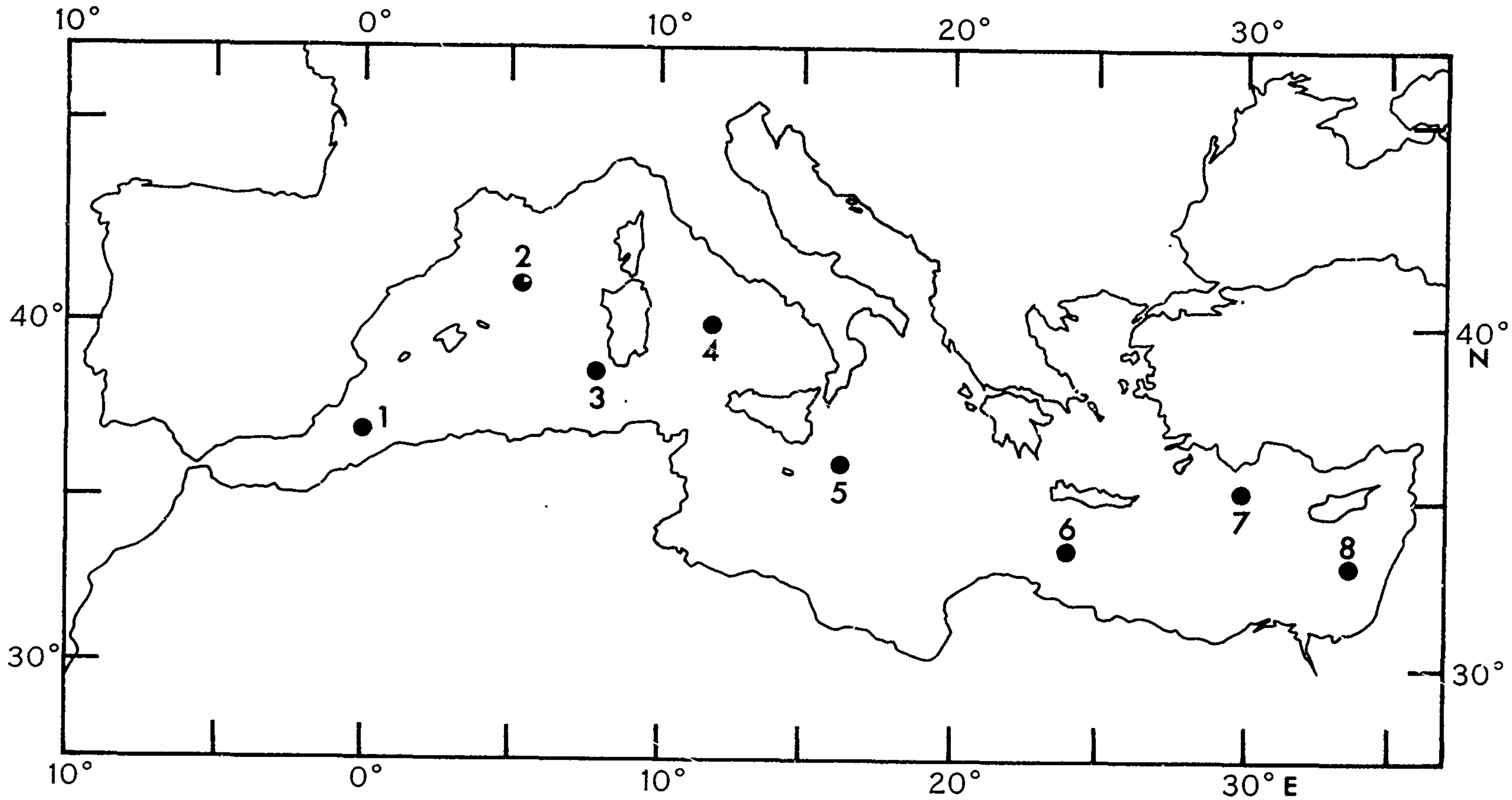


Figure A-4. Mediterranean Locations for FNWC Ambient Noise Estimates

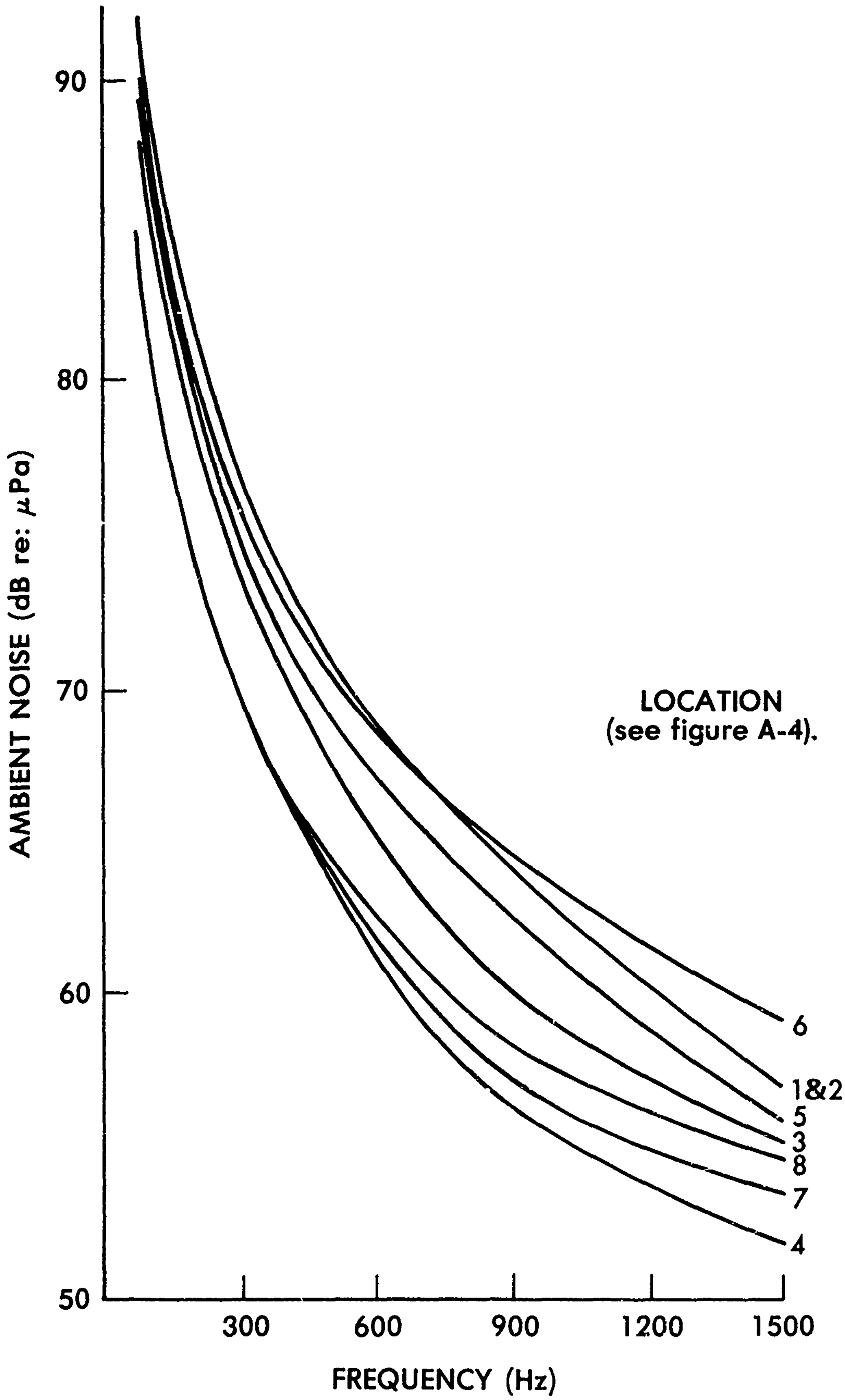


Figure A-5. Ambient Noise Levels for Selected Locations in the Mediterranean (Summer)

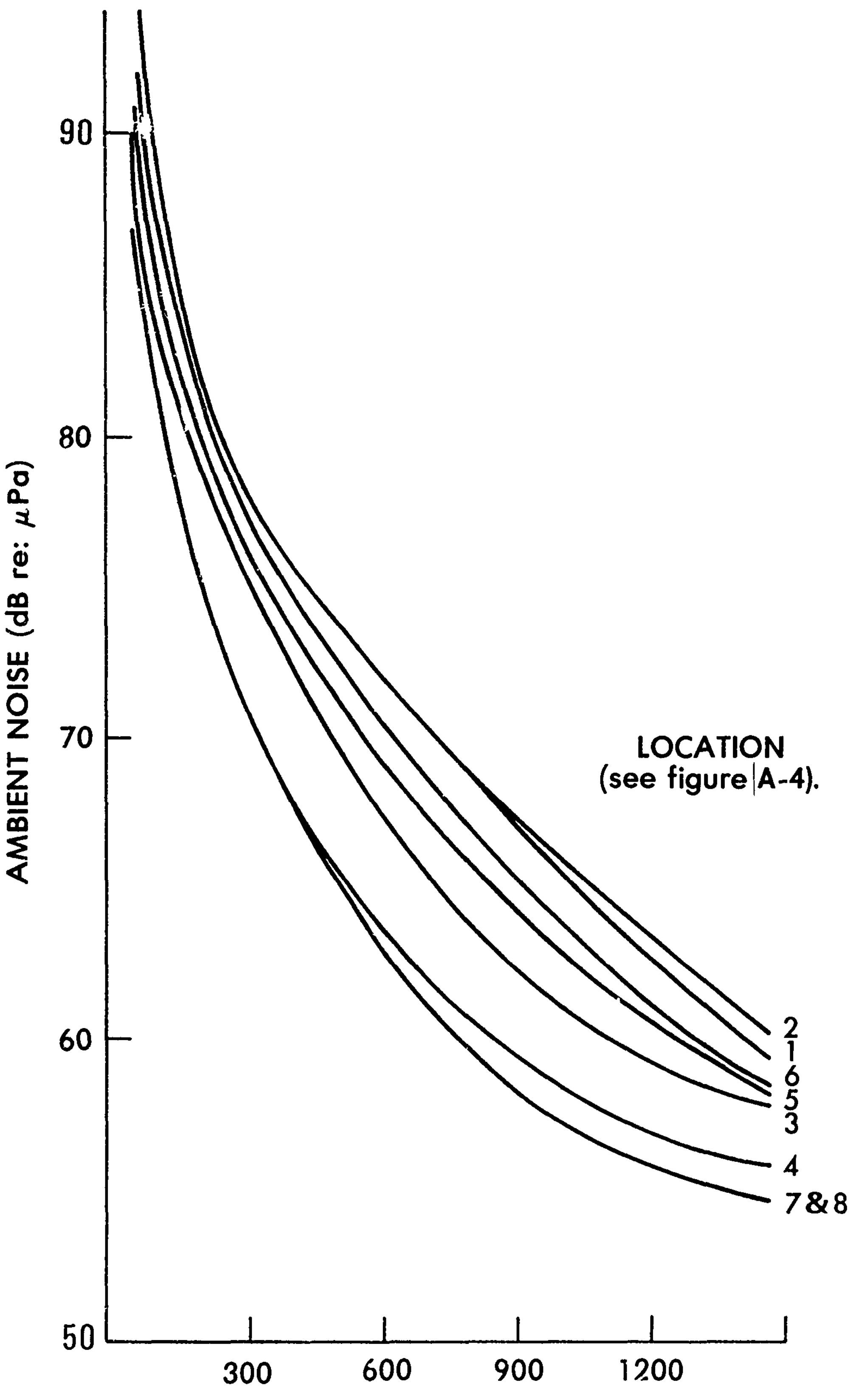


Figure A-6. Ambient Noise Levels for Selected Locations in the Mediterranean (Fall)

Subtracting 2 dB for the month of August gives 72 dB.

A significant wave height of 7 feet yields a 100 Hz noise intensity of 65 dB in Table A-1. The net ambient noise is obtained by entering Figure A-3 with the difference in intensities (72 - 65 = 7 dB) establishing a correction factor (1 dB), and adding that correction to the higher value from Table A-1: 72 + 1 = 73 dB.

The method for use in the Mediterranean is similar, though the boundaries for the areas represented by the sampling locations are not demarcated. Since both sea state and shipping traffic are seasonally and geographically dependent, the empirical curves incorporate the variation in source dominance. The user simply selects the location representative of the basin of operation (Figure A-4), and reads the noise level from the corresponding curve during the appropriate season (Figures A-5 and A-6).

While these approximations may suffice for advance planning, they are no substitute for direct measurement using calibrated equipment, particularly in the vicinity of a task force or heavily used shipping lane.

APPENDIX B

BIBLIOGRAPHY AND GLOSSARY OF ACRONYMS AND ABBREVIATIONS

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACTIVE ASRAP -- Active Acoustic Sensor Range Prediction

ADEPS -- Automated Detection Prediction System

AMOS -- Acoustic/Meteorological and Oceanographic Survey

AN -- Ambient Noise

APP -- Acoustic Performance Program

ASFS -- Automated Shipboard Forecasting System

ASW -- Antisubmarine Warfare

BLR -- Below-layer range

BT -- Bathythermograph

B/W -- Bassett/Wolff

CNO -- Chief of Naval Operations

CRT -- Cathode ray tube

CW -- Continuous wave

CZ -- Convergence zone

CZR -- Convergence zone range

CZW -- Convergence zone width

dB -- Decibel

FACT -- Fast Asymptotic Coherent Transmission

FM -- Frequency modulation

FNWC -- Fleet Numerical Weather Central

FOM -- Figure of merit

FTAS -- Fast Time Analysis System

GENRAYT -- General Ray Trace

Hz -- Hertz (cycles per second)

ICAPS -- Integrated Command ASW Prediction System

ILR -- In-layer range

kyd -- Kiloyard(s)

LATRAN -- Lateral Range

LOFAR -- Low frequency analysis and recording

MDR -- Median detection range

MIP-LORA -- Modest improvement package -- long range

NAVAIRDEVCEN -- Naval Air Development Center (Warminster, PA)

NISSM -- Navy Interim Surface Ship Prediction Model

nmi -- Nautical mile(s)

ODT -- Omnidirectional transmission

ONR -- Office of Naval Research

PDT -- Processed directional transmission

PL -- Propagation loss

PM -- Prairie masker

POD -- Probability of detection

PROFGEN -- Profile Generator

PSR -- Predicted Sonar Range

RD -- Recognition differential

RDT -- Rotational directional transmission

SC -- Scattering coefficient

SE -- Signal excess

SHAREM -- Ship ASW Readiness and Effective Measuring

SHARPS -- Ship Helicopter Acoustic Range Prediction System

SL -- Source level

SLD -- Sonic layer depth

SSP -- Sound speed profile

SVP -- Sound velocity profile (same as SSP)

TACTAS -- Tactical Towed Array System

TAPS -- Towed Array Prediction System

TASS -- Towed Array Surveillance System

TRAM-ODT -- Test of reliability and maintainability -- omnidirectional transmission

TSC -- Tactical Support Center

VDS -- Variable depth sonar

XBT -- Expendable bathythermograph

μPa -- Micropascal (10 dynes per square centimeter)

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August 1984

CHANGE NO. 4

RP 24, VOLUME II

Reference Publication RP 24, volume II, "Program Operating Procedures for the Integrated Command ASW Prediction System (ICAPS)," January 1982, should be updated as follows:

1. Replace pages v through viii.
2. Replace pages 2-3 and 2-4.
3. Replace chapter 7, "Fast Asymptotic Coherent Transmission (FACT) Model."
4. Replace chapter 11, "Ship Helicopter Active Range Prediction System (SHARPS) Model."

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the circulation pattern of their origin. Eddy life span varies from weeks in the case of a warm eddy to as long as two years for a cold eddy. Although eddies and meanders have most frequently been described along frontal systems such as the Gulf Stream and the Kuroshio, weaker anomalies no doubt occur near weaker fronts.

Longevity and intensity of fronts and eddies are greatly affected both by existing conditions of contiguous water masses and the overlying atmosphere. Cold eddies, being denser than the surrounding warm water, will sink at a rate of up to 1 m per day. Thus an old, cold eddy may not be evident from surface observations alone. Surface warming of fronts during summer frequently masks the surface indications of a front; however, subsurface horizontal temperature gradients and sound channels may exist throughout the summer. Warm eddies lose heat to the atmosphere faster than the surrounding cold water in winter with the result that surface cooling may mask the eddy. Masking also occurs in summer when the surface of the surrounding cold water may be warmed to near that of the eddy.

2.4 FRONTAL ACOUSTICS

An oceanographic front is not only a boundary separating temperature-salinity regimes, but also separates acoustic regimes. Because dynamic instability is inherent to frontal regions, acoustic conditions can be expected to vary considerably. Variations that occur during a frontal transit include:

-- Surface sound speed may differ as much as 30 m/s on either side of the front.

-- Differences in sonic layer depth of 300 m can exist on either side of the front depending upon season.

-- Changes in in-layer and below-layer gradients usually accompany changes in surface sound speed and sonic layer depth.

-- The depth of the deep sound channel axis may differ by as much as 800 m on either side of the front.

-- Increased biological activity generally found along a front will increase ambient noise and scattering.

-- Sea-air interaction in a frontal zone can cause a dramatic change in sea state when wind opposes ocean currents, thus increasing ambient noise.

-- Refraction of sound rays passing through a front at oblique angles may cause bearing errors.

-- Interaction of the water masses on either side of the front may cause near-surface sound channels (temperature inversions).

2.5 ACOUSTIC DATA MANIPULATION

Acoustic data normally plotted include SLD, areas where convergence zone (CZ) mode of sonar ranging is possible, and extent and axial depth of near-surface sound channels. Because sound speed data are rarely available to Fleet ASW units, sonic structure is normally estimated from thermal structure data. Therefore, the previous comments on processing of oceanographic data apply equally well to this section.

Sound speed is affected by depth and salinity as well as temperature. Although salinity has relatively little effect, depth (pressure) may have considerable effect on the determination of SLD. Where a slightly negative temperature gradient exists, the effect of depth may be sufficient to cause the sound maximum to occur at the bottom of the layer. For example, suppose that a near-isothermal layer occurred with a surface temperature of 15.1° and a temperature of 14.9° at a depth of 50 m. The 0.2°C temperature decrease in the layer implies a decrease in sound speed of 0.6 m/s. However, the effect of the 50-m depth increase causes an increase in sound speed of 0.8 m/s for a net increase of 0.2 m/s. SLD will thus be at the bottom of the slightly negative temperature layer.

A similar effect occurs in areas such as the Sargasso and Mediterranean Seas and in the Arctic, where a seasonal thermocline develops above a near-isothermal layer during spring and summer. A sound minimum occurs at the bottom of the seasonal thermocline and the effect of depth overrides the slightly negative temperature gradient forming a so-called "depressed" sound channel. The channel axis will normally be at the top of the layer.

When sound speed near the ocean floor is greater than that near the surface, some of the sonic energy originally refracted downward toward the bottom will be refracted upward toward the surface, forming a convergence zone. Range, width and intensity of the CZ is a function of depth excess; that is, the vertical distance between critical depth and the bottom. Depth excess generally must be at least 300 m if CZ propagation is to be operationally useful. Range to the inner edge of the first CZ annulus varies between 33 and 70 kyds, depending upon geographic area. Areas of high insonification at ranges less than 33 kyds, or where depth excess is insufficient for CZ propagation, are probably the result of bottom bounce (BB) propagation.

2.6 PLOTTING AND ANALYSIS

The experienced analyst develops techniques over the years that permit rapid plotting and analysis of environmental data. The following suggestions are provided as an aid in developing these techniques. In the example given only a portion of available data is used. The decision as to what data should be plotted depends upon what information is required for subsequent briefings. For example, determination and plotting of the temperature difference between 200 and 300 m (DT) is meaningless if it is not required for water mass identification.

The initial step in preparing an analysis is the collection and examination of available data. Obviously erroneous data should be discarded and questionable data identified. The analyst is encouraged to enter the data in a log both as an aid in preparation of the analysis and as a record for later reference. SST is generally available from XBT observations and injection intake thermometer reports. The latter data are particularly subject to errors and must be used with care. Temperature values at specified depths (200 and 300 m in the sample given) and, where desired, additional information are computed.

When ICAPS is being used as an analytical tool for tactical decision making, the analyst may wish to plot temperature at the 200-m level (T200) and the temperature difference between 200 and 300 m (DT) as an aid in water mass identification. The temperature difference between 200 and 300 m is computed using the relationship:

$$DT = T300 - T200$$

where T300 is the temperature at 300 m.

7.0 FAST ASYMPTOTIC COHERENT TRANSMISSION (FACT) MODEL

7.1 GENERAL

The FACT model computes acoustic propagation loss and provides acoustic performance predictions for passive omnidirectional sensors (e.g., AN/SSQ-41 sonobuoys) and for the passive directional sensor, the AN/SSQ-77 VLA (Vertical Line Array) DIFAR sonobuoy. FACT may be executed in either the omnidirectional (omni) mode or the VLA mode. In both modes FACT calculates propagation loss versus range for each target frequency and source/receiver depth pair combination specified. For propagation loss calculations below the surface duct, ray theory is used. In the surface duct, calculations are based on the Clay-Tatro model, modified to allow beam pattern corrections. The model provides only an approximation of duct leakage and rough-surface scattering of energy from the duct.

Losses considered by the FACT model include volume attenuation (geometric spreading and absorption), boundary scattering, and absorption at the bottom. Volume attenuation depends on horizontal range and frequency. Refractive effects on spreading are modeled by slicing the ocean into horizontal layers of constant sound speed gradient. Thus, the sound speed profile is made up of straight line segments joined at the boundaries between layers. Within each layer, the rays trace arcs of circles. The model doesn't consider losses through the ocean surface, but does include surface duct leakage loss at the sonic layer depth which is dependent on frequency and wave height. The ocean bottom is modeled as an imperfect reflector where losses are computed on the basis of ray grazing angle, frequency, and bottom province. To compute the loss due to these parameters for frequencies less than 1000 Hz, the Interim Bottom Loss Upgrade (IBLUG) curves are used. The Naval Oceanographic Office Navy Standard curves are used for frequencies of 1500 Hz and above with a transition zone between 1000 and 1500 Hz. Bottom loss increases with increasing bottom type index values and with frequency. Thus, greater care must be taken in selecting the proper type at high frequencies.

Assumptions of the FACT model are that the local environment is characterized by a single sound speed profile, a flat ocean bottom, a single low frequency bottom type, and a single high frequency bottom type. FACT is considered more reliable in deep water than in shallow water.

7.2 PROGRAM FUNCTION

The operator enters data according to an input menu (Reference Publication RP 24A, vol. 1, fig. 9-1). During execution these data are automatically retrieved from system data files. The operator supplies values for wave height, ASRAP frequency noise levels, target frequencies (up to four), source level, recognition differential, source/receiver depths (up to three pairs), and the number of 1-kyd range points (up to 200) for which propagation loss calculations are to be made. For VLA propagation loss calculations the receiver depth recommended for input is 1000 feet. The actual VLA depth may range from 900-1500 feet. Bottom depth, sonic layer depth, acoustic bottom types, and the sound

speed profile are retrieved from the intermediate file created by PROFGEN. VLA noise gain may be either input by the operator or computed by the FACT noise model.

The main option menu (fig. 7-1) provides the means to select only the model options necessary for the application at hand. Thus, if only omni propagation loss output is required, the VLA portions of FACT need not be executed. Output varies depending on the model options selected. FACT output displays include a summary of program input parameters (fig. 7-2) and the input sound speed profile (fig. 7-3). The propagation loss values calculated at each range point for the omni mode and/or the VLA mode are presented in tabular (figs. 7-4 and 7-5, respectively) and graphic (figs. 7-6 and 7-7, respectively) form for each source/receiver depth pair and frequency combination specified. Propagation loss graphics are displayed either one per page or two per page if more than one frequency is considered. If the one-graphic-per-page option is chosen, the propagation loss scale may be adjusted to enhance detail in the curve over a selected dB range. Ray trace graphics (fig. 7-8) show the paths followed by sound emanating from the source. Ray traces extend to either 100 kyds or 200 kyds at the operator's option. The depth scale may be set to 20,000; 10,000 or 2,000 feet to preserve detail for shallow bottoms. If required, 30,000 and 40,000 foot depth scales are automatically selected. Additional output displays depict the results of executing the: a) "VLA Beam Pattern" option (figs. 7-9 and 7-10; b) "VLA Noise Model" option (fig. 7-11); and c) "Omni vs. VLA Compare" option (fig. 7-12).

Omni propagation loss versus range output is stored in the intermediate work file where it is accessed by ADEP and other tactical models in the ICAPS software suite. VLA propagation loss output is not available for processing by ICAPS tactical programs.

7.3 VLA COMPUTATIONS

The output of FACT VLA computations is essentially an omni propagation loss versus range curve that has been modified according to the beamformer response of the AN/SSQ-77 sonobuoy. The beamformer response is a function of frequency, sensor type, and vertical arrival angle. For low frequency, characteristic of distant shipping, the beamformer rejects or nullifies sound arriving at nearly horizontal angles (fig. 7-13). For higher frequency, characteristic of wind noise, the beamformer response nullifies sound arriving from the sea surface (fig. 7-14). Examples of the FACT displays of beamformer response output are provided for low frequency (150 Hz) in figure 7-9 and for high frequency (600 Hz) in figure 7-10. The horizontal axis in each example figure corresponds to the vertical line array (bold vertical line of figures 7-13 and 7-14).

Because the VLA sensor nullifies sound arriving at certain angles depending on frequency, VLA propagation loss will likely be greater than propagation loss for an omnidirectional sensor. However, the propagation loss curves alone must not be used to compare the performance of the two sensor types. This comparison requires computing array noise gain, the "noise correction factor (NCF)" of FACT output. The NCF is the difference in decibels between omni ambient noise and VLA ambient noise as reduced by the beamformer response. Thus, because of the beamformer, VLA performance is degraded less by ambient noise than omni sensor performance.

```
*** FAST ASYMPTOTIC COHERENT TRANSMISSION LOSS MODEL ***
                         (FACT)

OPTIONS :

(1) INPUTS
(2) VLA BEAM PATTERN                X
(3) VLA NOISE MODEL                 X
(4) OMNI FACT PROP-LOSS MODEL       X
(5) VLA FACT PROP-LOSS MODEL        X
(6) OMNI VS VLA COMPARE
(7) TERMINATE FACT

 X  - INDICATES OUTPUT ALREADY COMPUTED

ENTER OPTION (1-7) :
```

Figure 7-1. FACT Main Option Menu

```
FACT INPUT PARAMETERS — OMNI  TESTRUN

      DATE =  3 / 1 / 84              LAT = 3700 N        LONG =  5500 W

NO. OF OBSERVED BT POINTS =  29
BT INPUT UNITS = 1 (1=METRIC,2=ENGLISH)
NO. OF SOUND-VELOCITY PROFILE POINTS =  39
NO. OF RANGE POINTS = 100
SONIC LAYER DEPTH (FT) =  295
WAVE HEIGHT (FT) =   2

NO. OF FREQUENCIES = 4
FREQUENCY (HZ)        BOTTOM PROVINCE
______________        _______________

      50
     150
     300
     600

NO. OF SOURCE-RECEIVER PAIRS = 1
SOURCE DEPTH (FT)      RECEIVER DEPTH (FT)
_________________      ___________________

       60                   1000
```

Figure 7-2 FACT - Summary of Input Parameters

1 MAR 84 TESTRUN
3700 N 5500 W

SONIC LAYER = 295 FT

VELOCITY	DEPTH
5001.02	0.
5006.27	10.
5010.00	295.
5009.61	325.
4998.66	364.
4998.12	387.
4992.32	427.
4986.06	446.
4981.93	486.
4982.26	505.
4978.80	531.
4976.64	587.
4975.30	774.
4973.01	837.
4971.98	909.
4959.48	1017.
4961.61	1073.
4953.08	1243.
4947.16	1293.
4945.09	1385.
4941.80	1470.
4935.71	1519.
4926.14	1578.
4920.44	1752.
4913.33	1837.
4909.65	1916.
4886.74	2303.
4883.19	2408.
4878.06	2500.
4872.23	3281.
4875.33	3609.
4879.65	3937.
5012.55	13123.
5080.08	17060.

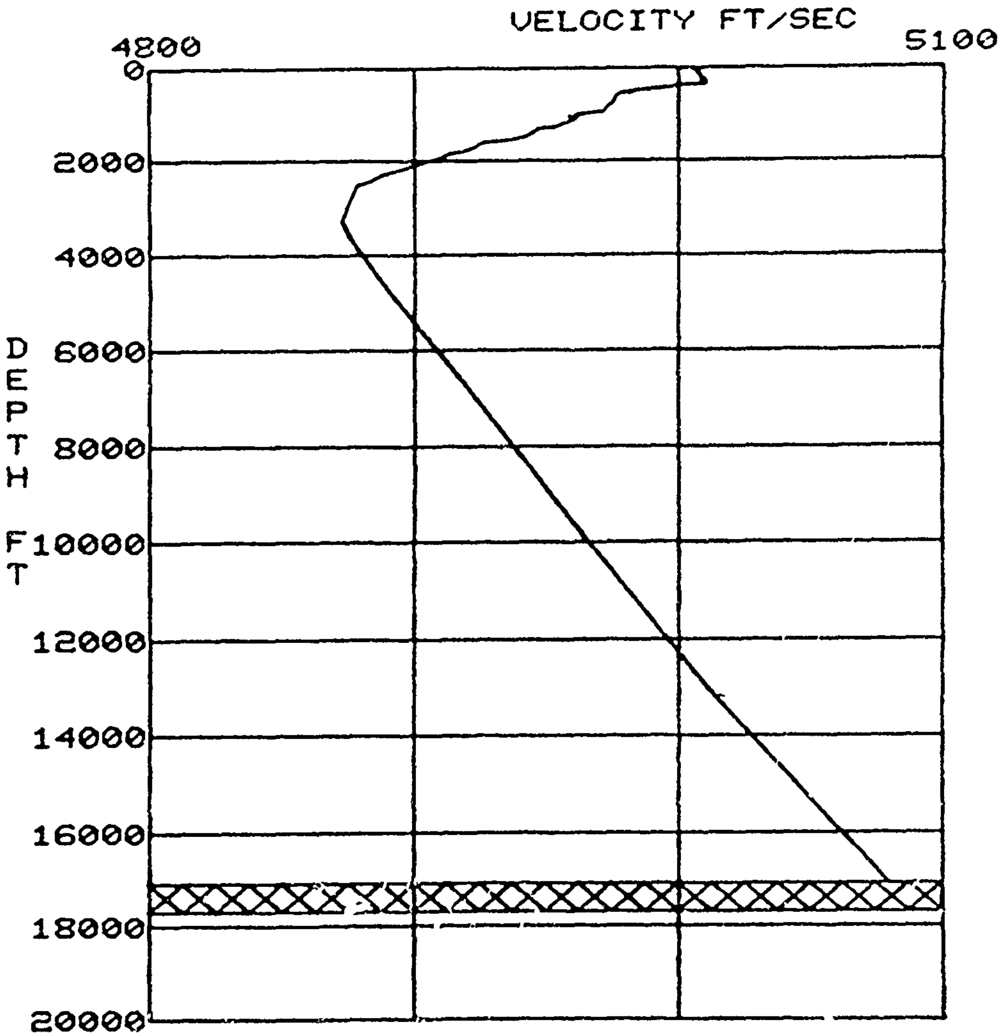

Figure 7-3. Sound Speed Profile Output

PROPAGATION—LOSS VALUES — OMNI TESTRUN

DATE = 3 / 1 / 84 LAT = 3700 N LONG = 5500 W

WAVE HEIGHT........ 2 FT
SONIC LAYER DEPTH.. 295 FT
SOURCE DEPTH... 60 FT
RECEIVER DEPTH. 1000 FT
FREQUENCY...... 150 HZ

RANGE (KYDS)	1	2	3	4	5	6	7	8	9	10
1	56.9	65.8	72.4	77.0	80.4	82.9	84.9	86.3	86.8	87.2
11	87.5	87.9	83.1	83.2	83.4	83.5	83.7	83.9	84.0	84.2
21	84.4	84.5	84.7	84.9	85.0	84.9	84.8	85.0	85.1	85.2
31	85.4	85.5	85.7	85.8	86.0	86.1	86.3	86.4	86.5	86.7
41	86.8	86.9	87.1	87.2	87.4	87.6	87.8	87.9	88.1	88.3
51	88.5	88.7	89.0	89.2	89.4	89.7	90.0	90.2	90.5	90.8
61	91.1	90.2	83.2	77.7	81.2	82.3	83.4	89.0	77.0	80.8
71	87.5	88.9	90.0	90.8	91.4	91.9	92.3	92.6	92.8	93.1
81	93.2	93.4	93.5	93.6	93.7	93.8	93.8	93.8	93.9	93.9
91	93.9	94.0	94.0	94.1	94.1	94.1	94.2	94.2	94.3	94.4

Figure 7-4. Tabular Propagation Loss Display (Omni)

PROPAGATION-LOSS VALUES - VLA1 TESTRUN/VLA

DATE = 3 / 1 / 84 LAT = 3700 N LONG = 5500 W

WAVE HEIGHT........ 2 FT
SONIC LAYER DEPTH.. 295 FT

SOURCE DEPTH... 60 FT
RECEIVER DEPTH. 1000 FT
FREQUENCY...... 150 HZ

RANGE (KYDS)	1	2	3	4	5	6	7	8	9	10
1	66.6	86.4	88.4	88.9	89.3	89.7	90.1	90.6	91.1	91.5
11	91.9	92.1	87.1	87.1	87.0	87.1	87.2	87.3	87.6	87.9
21	88.2	88.6	89.0	89.5	90.0	90.2	90.3	90.8	91.2	91.6
31	92.0	92.4	92.8	93.2	93.5	93.8	94.2	94.4	94.6	94.7
41	95.0	95.2	95.4	95.6	95.8	96.0	96.2	96.4	96.6	96.8
51	97.0	97.2	97.3	97.5	97.7	97.9	98.1	98.3	98.5	98.7
61	98.8	99.0	98.7	96.9	97.5	97.4	97.4	99.9	96.1	97.2
71	100.4	100.6	100.8	101.0	101.1	101.3	101.4	101.6	101.7	101.9
81	102.0	102.2	102.3	102.4	102.6	102.7	102.8	102.9	103.1	103.2
91	103.3	103.5	103.6	103.7	103.7	103.8	103.9	104.0	104.1	104.1

Figure 7-5. Tabular Propagation Loss Display (VLA)

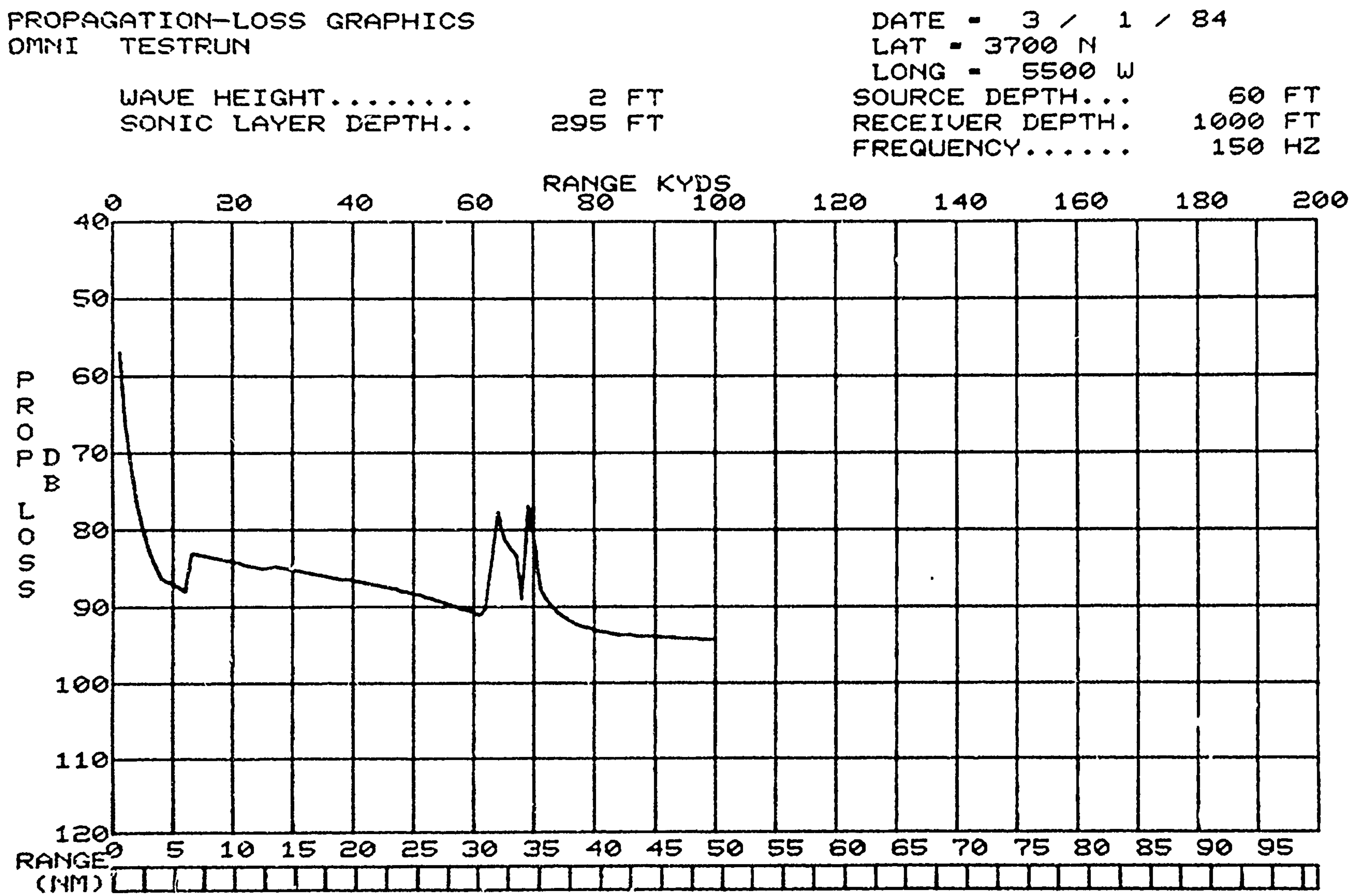

Figure 7-6. Graphic Propagation Loss Display (Omni)

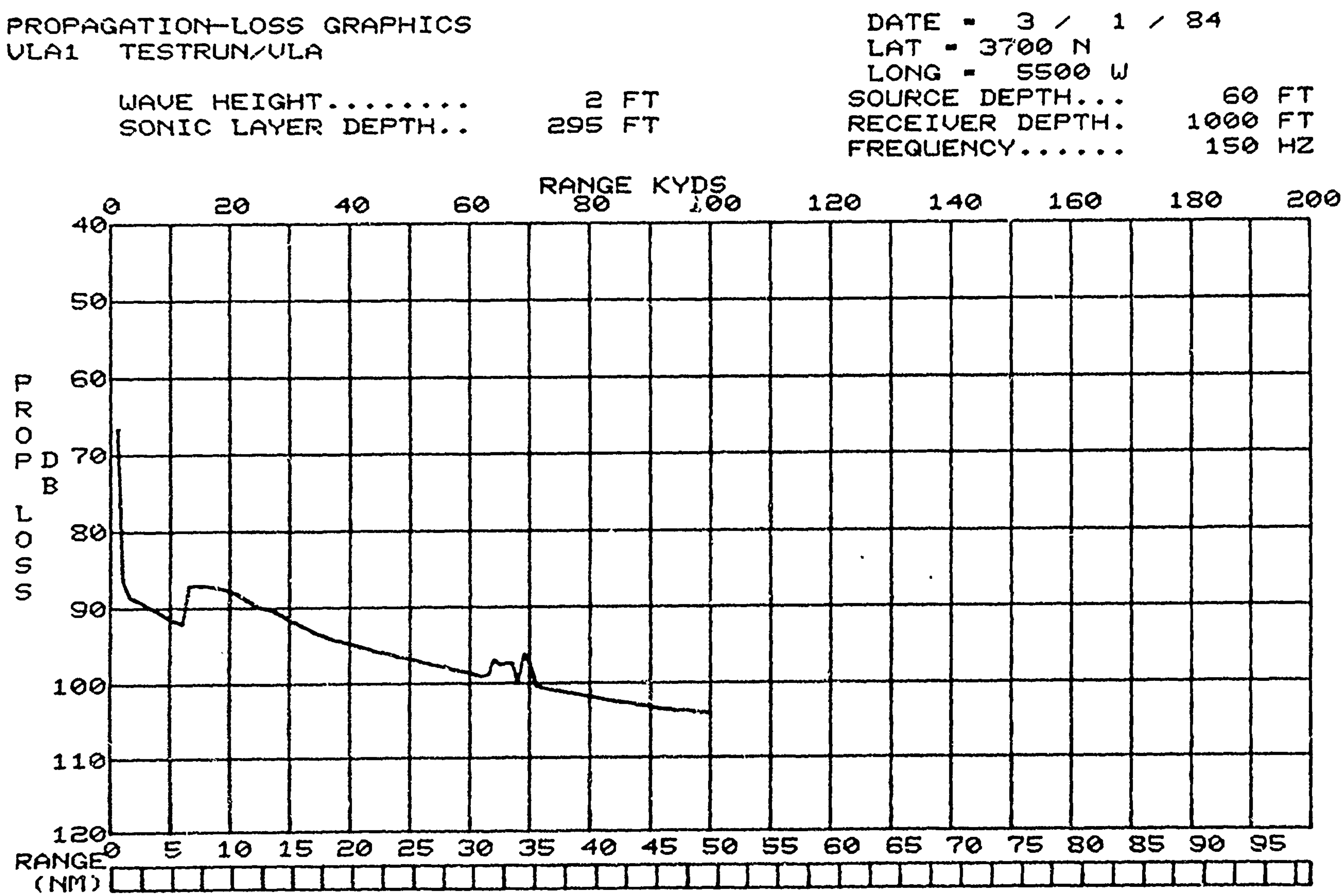

Figure 7-7. Graphic Propagation Loss Display (VLA)

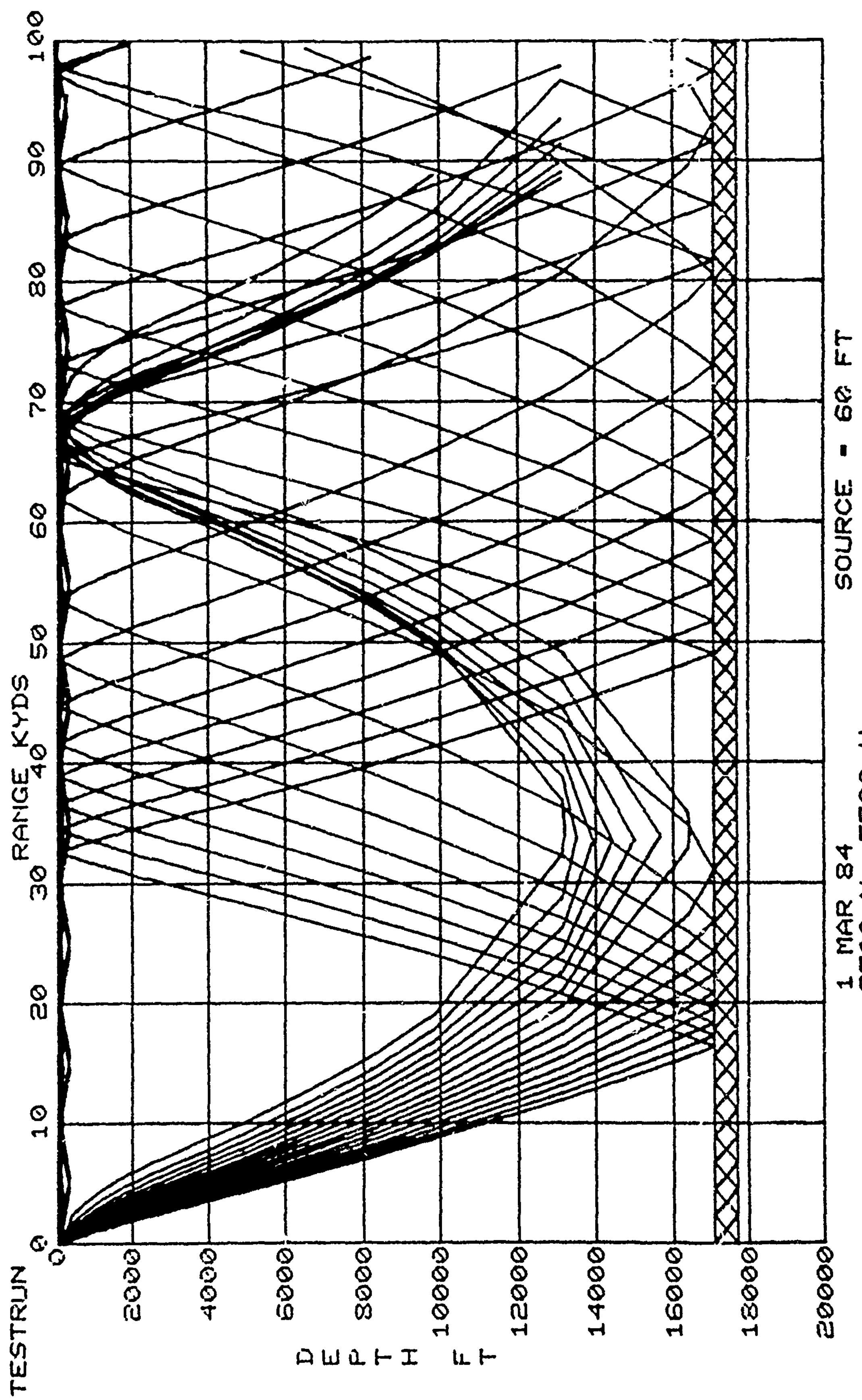

Figure 7-8. FACT Ray Trace

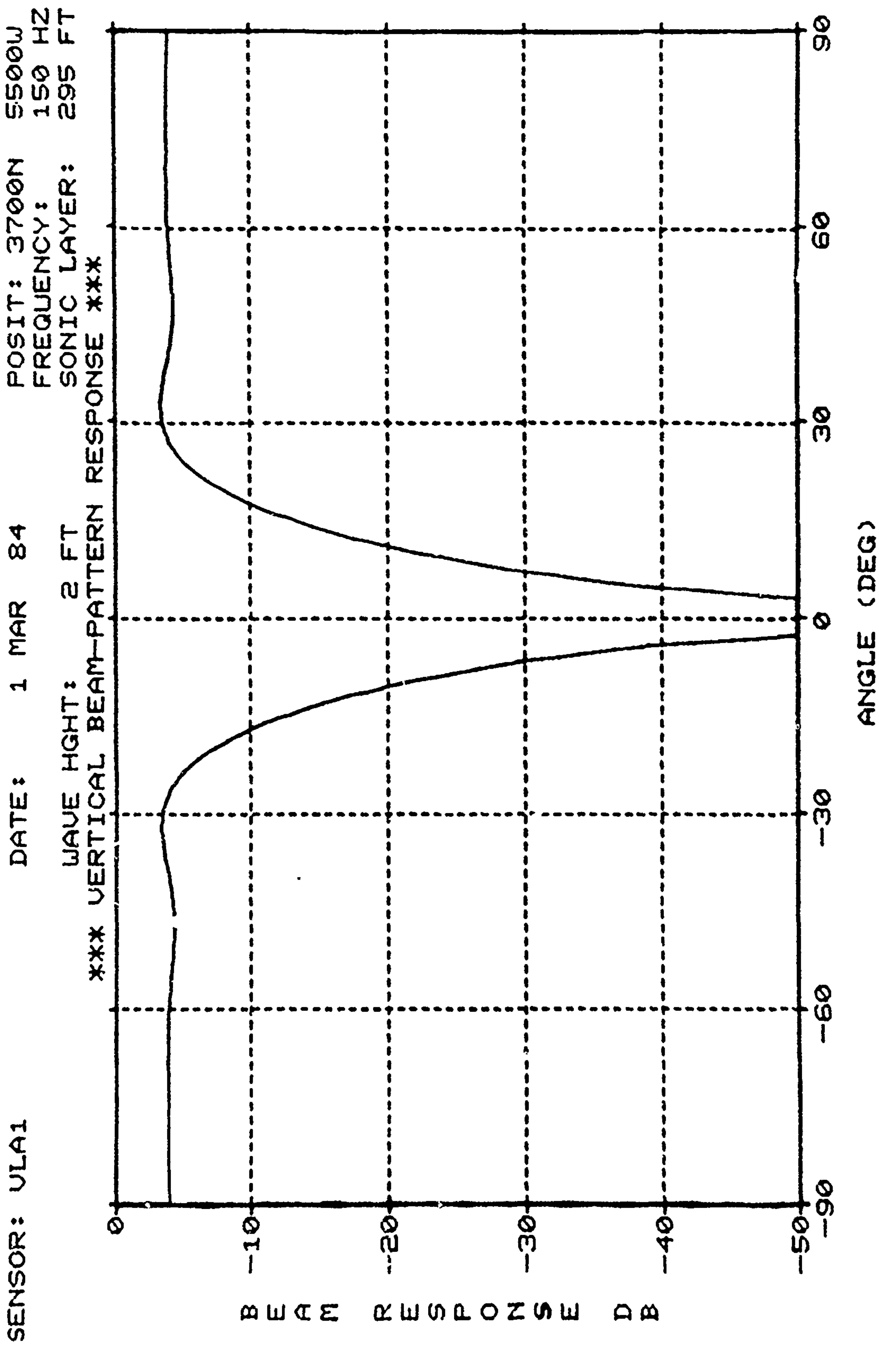

Figure 7- 9 . AN/SSQ-77 VLAD Beamformer Response at 150 Hz

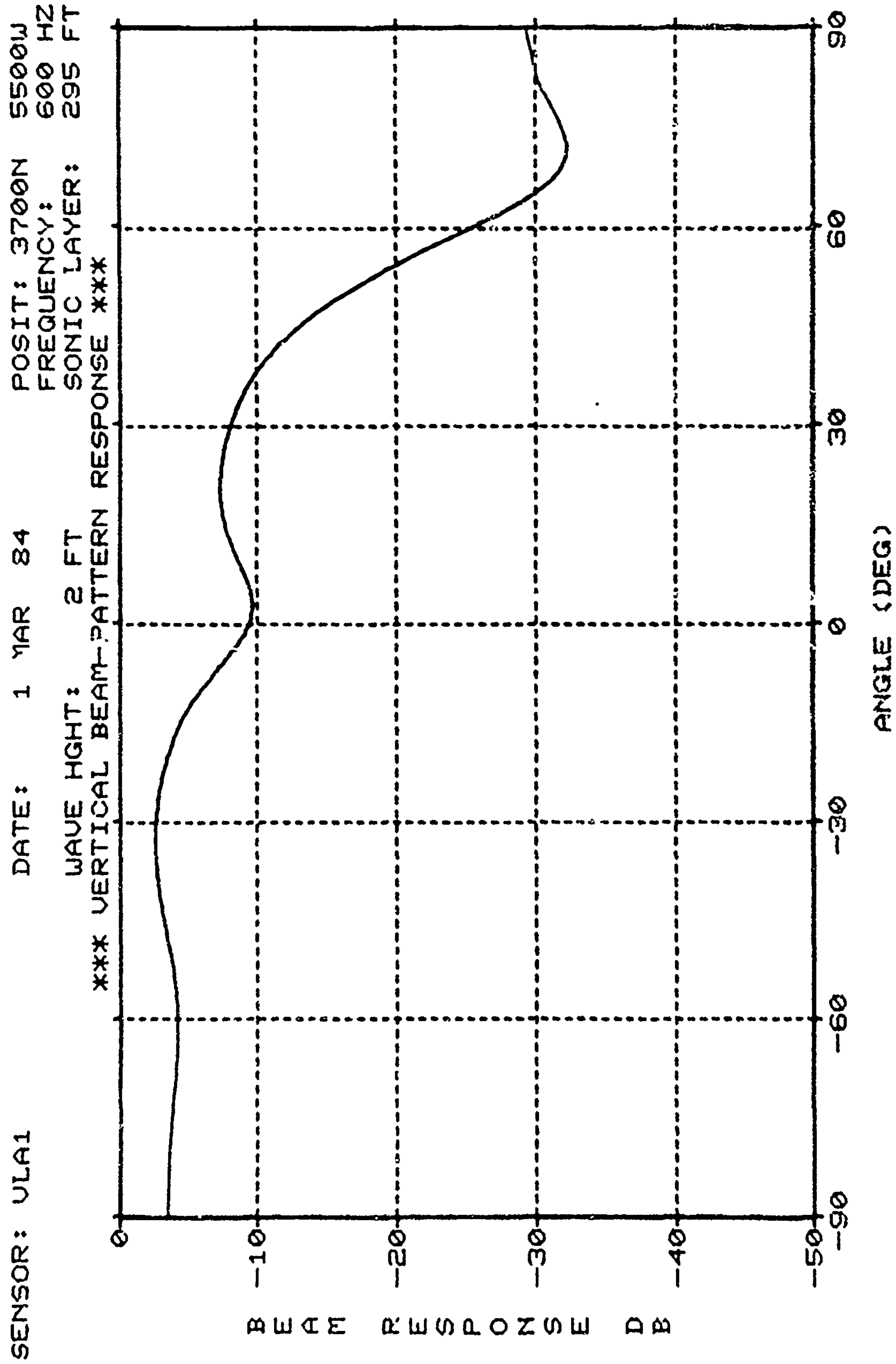

Figure 7-10. AN/SSQ-77 VLAD Beamformer Response at 600 Hz

SENSOR: VLA1

DATE: 1 MAR 84
RECEIVER: 1000 FT
WAVE HGHT: 2 FT

POSIT: 3700N 5500W
SONIC LAYER: 295 FT

*** NOISE SUMMARY ***

FREQUENCY (HZ)	WIND (DB)		SHIPPING(DB)		TOTAL(DB)	
	OMNI NOISE	BEAM NOISE	OMNI NOISE	BEAM NOISE	OMNI NOISE	BEAM NOISE
50	63	57 (-6)	94	78 (-16)	94	78 (-16)
150	67	61 (-6)	81	64 (-17)	81	66 (-15)
300	70	65 (-5)	72	58 (-14)	74	66 (-8)
600	66	57 (-9)	56	48 (-8)	67	57 (-10)

( ) = NOISE CORRECTION FACTOR
= BEAM NOISE - OMNI NOISE

NOTE : VLA FOM = OMNI FOM - TOTAL NOISE CORRECTION FACTOR

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Figure 7-11. FACT VLA Noise Model Output

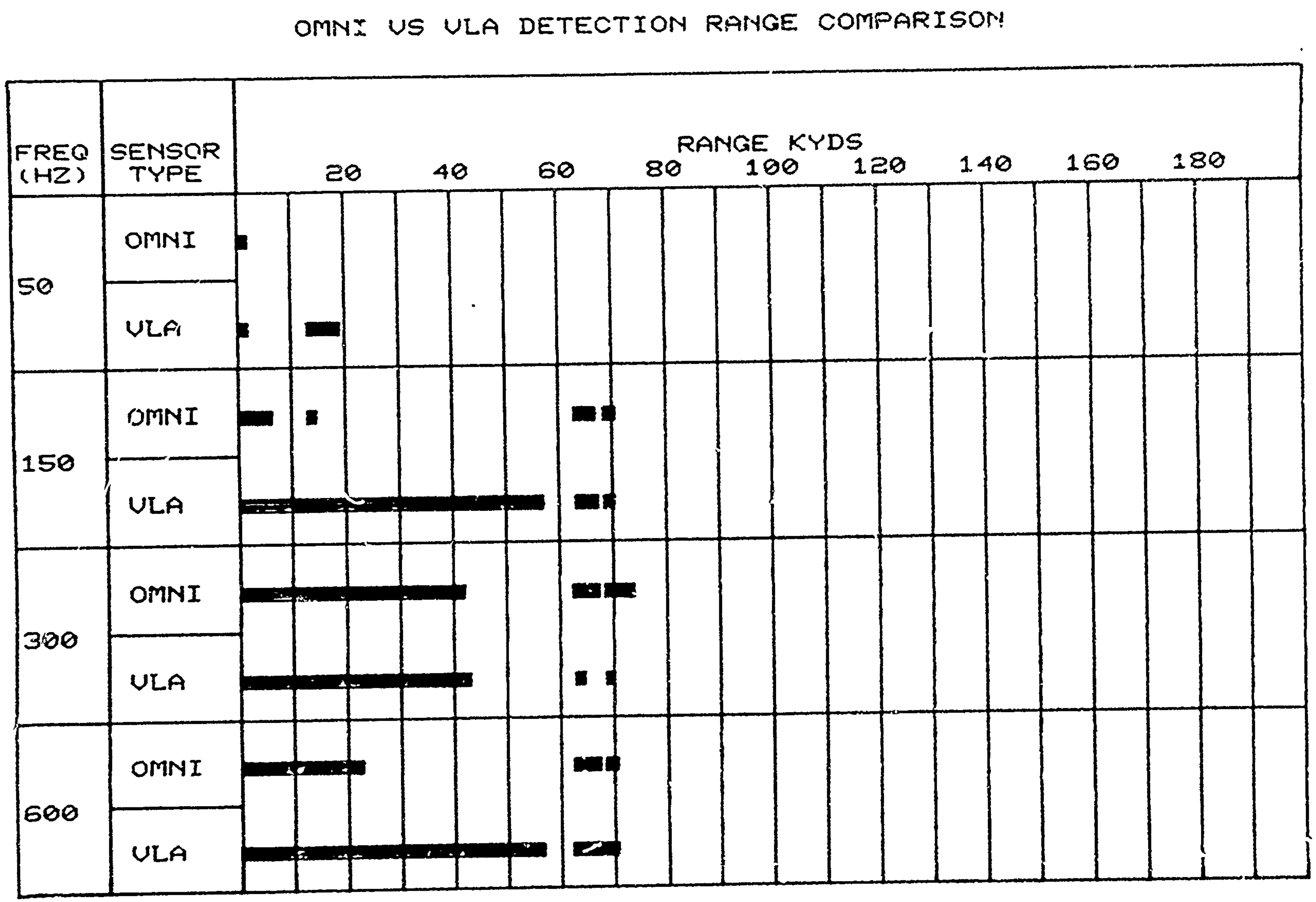

Figure 7-12. FACT Omni vs VLA Comparison

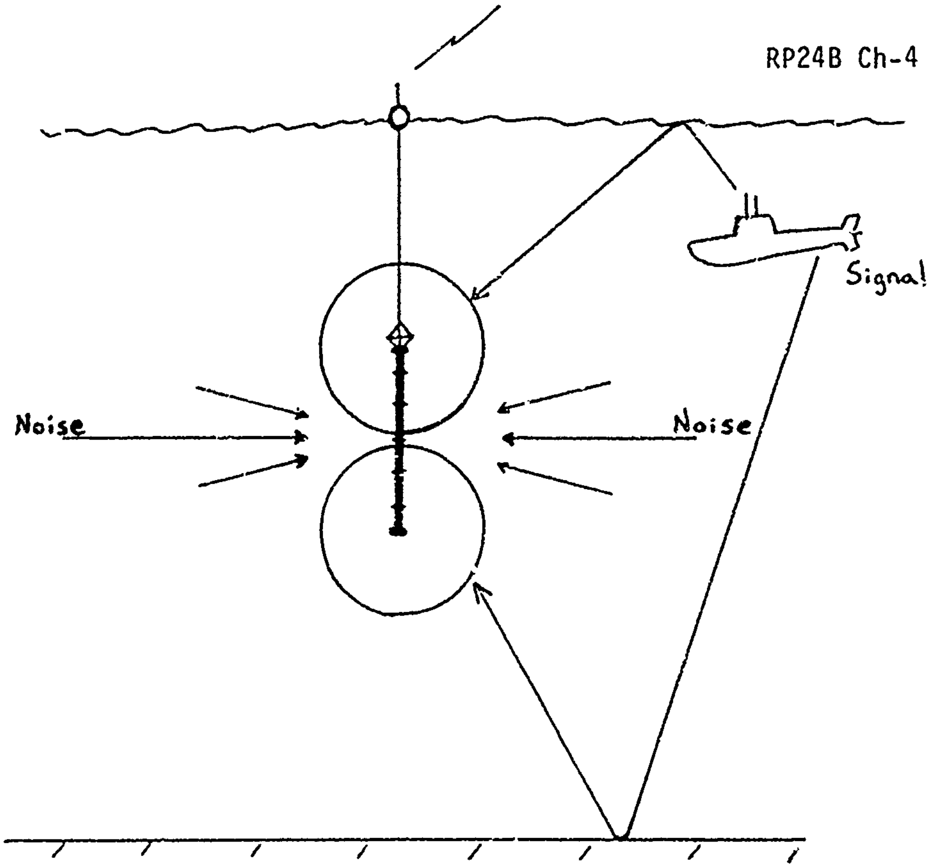

Figure 7-13. Low Frequency (~150) VLA Beamformer Response

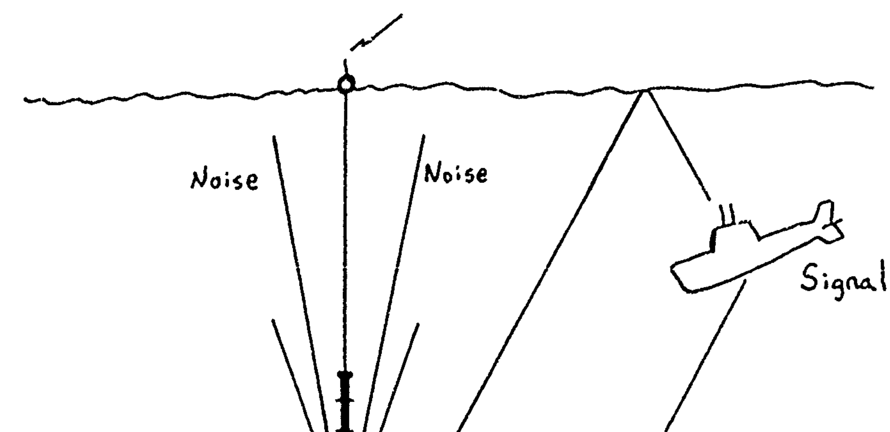

Figure 7-14. High Frequency (~600 Hz) VLA Beamformer Response

The NCF is computed for each target frequency based on operator input of ambient noise levels (decibels) at the ASRAP frequencies (50, 300, 850, and 1700 Hz). The model separates the ASRAP noise levels into assumed components, wind noise and distant shipping noise. These wind and shipping components are then used to derive the wind and shipping components for the target frequencies.

Next, the model determines the vertical arrival structure (i.e., noise level vs. arrival angle) for each target frequency ambient noise component. The beamformer response values are added to these noise levels for all angles -90 to +90 degrees from the horizontal. By summing over all angles, the total beamformer-reduced noise level for each component of each target frequency is computed. The component noise levels (wind and shipping) for a given target frequency are then combined by power summation to yield the total beam noise for that frequency. Omni noise components (the components without beamformer response values added) are combined for each frequency by power summation. The difference between the total beam noise and the total omni noise is the NCF for a given frequency. FACT noise model output includes noise levels for omni wind, omni shipping, omni total, VLA (Beam) wind, Beam shipping, and Beam total. In addition to the total NCF, wind NCF and shipping NCF are also given (fig. 7-11). The total NCF is used to compute the Figure of Merit (FOM_{VLA}):

$$FOM_{VLA} = FOM_{omni} - NCF \qquad (1)$$

where $FOM_{(omni)}$ = SL - AN - RD (2)
= FOM for the omni sensor
SL = target source level (dB//uPA/Hz^{½}),
AN = omni ambient noise (dB), and
RD = processing recognition differential (dB).

Because the total NCF is negative, FOM_{VLA} will be greater than FOM_{omni}. The computed FOMs are applied to the respective propagation loss curves to show the ranges where probability of detection is at least 50 percent. Evaluation of these detection range displays (fig. 7-12) is a valid way to compare omni and VLA performance.

7.4 APPLICATIONS

Ray trace and omni propagation loss graphics help the analyst determine what transmission modes are in effect, which modes prevail at certain ranges, where shadow zones exist, what receiver depth settings are optimal, and so on.

The OMNI/VLA detection range comparison output permits evaluation of sensor performance to provide the operator a means of selecting which sensor to use for given environmental conditions. This output is also useful in identifying median detection range (MDR), convergence zone range (CZR), and convergence zone width (CZW).

The VLA can be expected to give increased detection ranges over omni sensors in deep water where low frequency ambient noise is primarily caused by distant shipping. This results because energy from such shipping tends to arrive at near horizontal angles and the VLA filters out noise arriving at these angles through the beamformer response. The vertical line array should not be used when surface ships are within the first convergence zone since much of this

ship noise will arrive at angles selectively sensed by the array according to the beamformer response. Thus, for the VLA sensor, noise from nearby ships tends to mask the target signal.

The VLA noise gain model should not be used in shallow water areas (<1800 meters, <6000 feet) and in areas of high variability in water mass, bottom depth, and/or shipping traffic.

11.0 SHIP HELICOPTER ACTIVE RANGE PREDICTION SYSTEM (SHARPS) MODEL

SHARPS is an active propagation loss model which computes ranges for surface ship hull-mounted sonars, variable depth sonars, helicopter dipping sonars, and active sonobuoys. Navy Interim Surface Ship Sonar Prediction Model II (NISSM II), incorporating ray tracing techniques and empirical formulas based on the Acoustic Meteorological and Oceanographic Survey (AMOS) equations, is used to calculate the sonar range. It uses a single sound speed profile and flat bottom to compute ranges. The sound speed profile is developed from the data contained in the intermediate working file (Z999ICAP:IM). The current version of the SHARPS model is SHARPS III.

Range predictions based on user-selected probability of single-ping detection by an unalerted operator are provided for the sonars chosen by the operator. Up to nine sonars and their characteristics/parameters may be entered in the sonar parameters file. Once the sonar parameters are entered, they need not be input again unless a parameter changes or a different sonar is required. The user has the option to make predictions for any or all of the sonars contained in the sonar parameters file. Characteristics/parameters in the sonar parameters file are provided for the following sonars using average equipment operating parameters:

SQS-39
SQS-41
SQS-26 (steel)
SQS-26 (rubber dome - OM)
SQS-23
SQQ-23
SQS-35 VDS
AQS-13

Input parameters include wave height (used to calculate self noise), wind speed (for calculating ambient noise), bottom type, volume and layer scattering coefficients, target strength, probability of detection, target depths, and sensor depths. Default values or values from Z999ICAP:IM are supplied for the operator to use or change as desired.

SHARPS output consists of tables of active and passive ranges for both in-layer (ILR) and below-layer (BLR) at the specified speeds and modes of operation. The format is identical to the Fleet Numerical Oceanography Center SHARPS III message. All ranges are in hundreds of yards. The Depth Required (DR) and Depth Excess (DX) for convergence zone propagation are in fathoms. Counter Detection Continuous (CDC) tracking is the maximum range for continuous tracking of the active sonar by a BQR-2B equipped submarine at 300 feet. Counter Detection Maximum (CDM) is the maximum range at which a BQR-2B equipped submarine can detect that active sonar.

The deep target or below layer target is placed at the sonic layer depth plus 200 feet (but no greater than 1000 ft) if the user does not specify a deep target depth.

Convergence Zone Widths (CZW) contain the onset (inner annulus) range and the ending (outer annulus) range in hundreds of yards. A blank or zero for CZW ranges and Depth Excess (DX) indicates that no convergence zone path exists for those oceanographic conditions.

For hull-mounted sonars, sonar depth is fixed at 20 feet. For VDS and dipping sonars the operator may input sonar depth or let the program select the depth through an internal algorithm which is based on tactical doctrine.

The last set of predictions may be redisplayed by following the procedures listed in Volume I.

11.1 USER HINTS

All users should note that SHARPS is intended for use at frequencies above 1500 Hz. Any sonar parameter frequencies below 1500 Hz can be expected to give erroneous results.

When the following ERROR message occurs - "ERROR - Profile too complicated, reduce number of profile points" - the user should look at the BT trace to see which points may be left out. Be careful when deleting points to ensure that inflection points are not deleted. Once the user is satisfied with the modified BT profile, it must be run through PROFGEN before rerunning SHARPS.